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PORTO RICO AGRICULTURAL EXPERIMENT STATION,
FRANK D. GARDNER, Special Agent in Charge,
Mayaguez, September, 1903.

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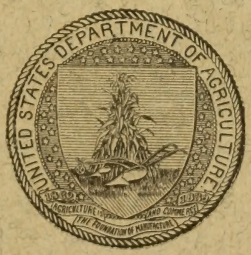
Soil Survey from Arecibo to Ponce, Porto Rico.

BY

CLARENCE W. DORSEY, LOUIS MESMER, AND THOMAS A. CAINE,
Assistants in the Bureau of Soils, U. S. Department of Agriculture.

[Reprinted from Report of Field Operations of the Bureau of Soils, 1902.]



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1903.

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PORTO RICO AGRICULTURAL EXPERIMENT STATION.

[Under the supervision of A. C. True, Director of the Office of Experiment Stations, United States Department of Agriculture.]

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FRANK D. GARDNER, *Special Agent in Charge.*
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E. C. HOWE, *Clerk and Stenographer.*

Withdrawn
8/12/48

LETTER OF TRANSMITTAL.

MAYAGUEZ, PORTO RICO, *September 8, 1903.*

SIR: I have the honor to transmit herewith a report entitled "Soil Survey from Arecibo to Ponce, Porto Rico," which was made under instructions from Prof. Milton Whitney, Chief of the Bureau of Soils, U. S. Department of Agriculture, by Messrs. Clarence W. Dorsey, Louis Mesmer, and Thomas A. Caine, assistants in that Bureau, with the cooperation of this station, and published as a part of the Report of Field Operations of the Bureau of Soils, 1902, and to recommend that it be reprinted as Bulletin No. 3 of this station. The area included in this study extends 5 miles each side of the Government road recently constructed from Arecibo to Ponce, and embraces many types of soil which are represented in other parts of the island.

Respectfully,

FRANK D. GARDNER,
Special Agent in Charge.

Dr. A. C. TRUE,
Director, Office of Experiment Stations,
U. S. Department of Agriculture, Washington, D. C.

Recommended for publication:
A. C. TRUE, *Director.*

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JAMES WILSON,
Secretary of Agriculture.

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SOIL SURVEY FROM ARECIBO TO PONCE, PORTO RICO.

By CLARENCE W. DORSEY, LOUIS MESMER, and THOMAS A. CAINE.

LOCATION AND BOUNDARIES OF THE AREA.

The island of Porto Rico is the fourth in size of the Greater Antilles group of the West Indies. Its area is approximately 3,600 square miles, or about four times the land surface of Long Island. Lying between 17° 55′ and 18° 30′ north latitude and 65° 39′ and 67° 11′ west longitude, the island is distant from the most eastern point of Cuba 450 miles and from New York 1,400 miles. Haiti, the nearest island of importance, is 75 miles distant, due west. (See fig. 1.)

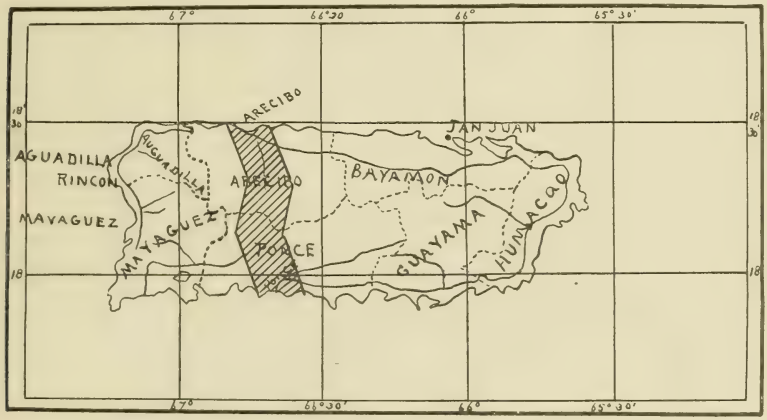


FIG. 1.—Sketch map showing area surveyed in Porto Rico.

The present soil survey covers an area of 211,180 acres, or about 330 square miles, in the western half of the island, comprising a strip 10 miles wide—5 miles on each side of the military road—extending from Arecibo, on the north coast, to Ponce, on the south. As no accurate topographic survey had been made of the area, it was found necessary to precede the soil survey by a traverse party, which was, however, composed of men in the soil-survey party, and the soils were plotted on a base prepared in this way. The traverse work was checked on both coasts with United States Coast and Geodetic Survey maps, with which it was found to agree nicely. It is believed that this insures the reasonable accuracy of the boundaries of the soil areas in the interior of the island.

The Porto Rican soil survey was undertaken at the request of the Office of Experiment Stations, which through the cooperation of the agricultural experiment station of the island rendered assistance and advice and paid a part of the field expense of the work.

HISTORY OF SETTLEMENT AND AGRICULTURAL DEVELOPMENT.

Porto Rico was discovered by Columbus on his second voyage to America (1493), but it was not until 1510 that the first attempt at colonization was made by Spain. In that year Ponce de Leon founded the city of Caparra, soon afterwards abandoned, and in the following year, with more success, San Juan de Bautista, later called Puerto Rico, and now San Juan.

From its discovery to its acquisition by the United States Porto Rico continued a Spanish possession, although attacked many times by foreign nations, especially by the English, and harried by freebooters and pirates. Drake sacked San Juan in 1595, and Abercrombie, in 1797, in what was the most formidable expedition ever planned against the colony up to that time, laid siege to San Juan and the Morro castle for thirteen days. But he found the great stone fortress impregnable and was forced to withdraw his fleet and army of 3,000 men. The hundred years intervening between this attack and the occupation of the island by the United States troops saw no interference with Spanish rule, if we except one single and very feeble movement of the islanders for independence early in the nineteenth century, which was promptly quelled.

During the first three centuries of her dominion Spain paid but little attention to this small island possession, but as one by one Mexico and her other richer colonies revolted and were lost, Porto Rico became of relatively greater importance and was the object of greater exploitation. Data of the growth of population and the extension of settlement in the earlier years are meager. No definite reports of the fiscal and other administrative departments of government were made until toward the end of the eighteenth century. The population was increased to some extent by immigrants from San Domingo and the French settlement in Haiti, driven out by the insurrection of the negroes against the whites, which occurred in 1789 and the years closely following. Settlement was encouraged during a limited period following 1815 by a royal decree granting free land to colonists, the amount being proportioned to the number of slaves owned. These lands were exempted from taxation for a period of ten years, and the settlers were relieved for a like period from the payment of either import duties on agricultural machinery or export duties on the products of their plantations.

In 1765 the population of the island was 44,883; in 1802 it had increased to 163,192, and in 1899 to 953,243. The density of population is to-day seven times greater than that of Cuba, and greater than

that of any of the States except Massachusetts and Rhode Island. About three-fifths of the population are white, the proportion of whites to negroes, pure or mixed blood, being about the same as in Virginia, and greater than most of the Southern States. There are now in Porto Rico 57 towns with a population of 1,000 or over. Four of these—San Juan (32,048), Ponce (27,952), Mayaguez (15,187), and Arecibo (8,008)—have populations above 8,000. Ponce and Arecibo are situated within the area surveyed.

The population of Porto Rico is largely rural, the percentage of urban population for the different civil departments, according to the last census, ranging from 13 to 29 per cent of the total population. The percentages for the departments of Arecibo and Ponce, within which the area surveyed lies, were 13 and 23 per cent, respectively.

The agricultural development of the island has been based mainly on the production of sugar and coffee, while stock raising has also been an important factor, and tobacco, and more recently fruit, have contributed a considerable part to the revenues received from articles exported.

In 1815 sugar cane was brought into the island from Haiti, where Columbus had introduced it on his second voyage, but only molasses was manufactured until 1548, when the first mill for the production of sugar, to be run by water, was built. In 1581 there were 11 mills in operation whose aggregate production amounted to 15,000 arrobas (375,000 pounds, or 187 tons).

Many fluctuations in the production of sugar have taken place. At one time in the seventeenth century the cultivation of cane was almost entirely displaced by the cultivation of ginger, and a royal decree prohibiting the growing of the latter crop and governmental aid in rebuilding of sugar mills had to be resorted to in order to resuscitate the languishing industry. The wrecking of the mills and the destruction of the crops by hurricanes has now and again almost ruined the industry.

The exportation of sugar reached its maximum in 1879, when 170,000 tons, the product of 553 mills, were shipped from the island. From that point the exports, which may be taken as an index of production, declined to a minimum of 47,000 tons in 1893, whence they have slowly risen to about 90,000 tons in 1899.[a]

This later decline in the production has been due principally to the low price of sugar and the impossibility of manufacturing sugar at a profit with the old methods and old machinery that have been in use in the great majority of Porto Rican mills. Scattered over the island one sees many sugar mills of the old type disused and rapidly going to ruin. To equip a modern mill a capital of from $350,000 to $500,000 is

[a] See Bulletin on Porto Rico, Bureau of Statistics, Treasury Department.

needed, an amount so large that few individual planters are in a position to change their mill equipments to meet the new conditions of competition. The tendency is, therefore, toward the centralization of the industry, the establishment of large mills—partly cooperative—and the absorbing of the smaller by the larger plantations.

These few main facts give some idea of the development of the sugar industry in the island at large and apply pertinently to the area surveyed. At present sugar cane is relatively of less importance in the Department of Arecibo, where, according to the latest figures, it occupies 5 per cent of the cultivated area, than in any of the other departments. The proportion in Ponce is three times as great.

Coffee was introduced into the other Antilles from Martinique, where it was first planted in 1720, by M. Declieux, who brought the seed from the Botanical Garden in Paris. It is believed to have been brought into Porto Rico by French refugees from Haiti in the eighteenth century. The production amounted to 728,025 pounds in 1770, and by 1776, through the remission of taxes, the production had nearly doubled. The market at that time was limited to Mediterranean ports, and coffee production did not hold an important place in the agriculture of the island until nearly one hundred years later, when the admission of coffee into the United States gave a great impetus to the industry. In 1850 the production amounted to 11,783,684 pounds, in 1870 to 17,416,762 pounds, and in 1897 to 51,710,997 pounds. The crop of 1898 would have been very large had it not been almost wholly destroyed by the severe hurricane of that year.

Recent statistics place the proportionate acreage of coffee at 36 per cent of the cultivated area of the island. In the Department of Arecibo the crop now normally occupies 50 per cent, and in Ponce 43 per cent, of the cultivated area.

Tobacco is indigenous to the island, but in the earlier years of settlement its cultivation was interdicted, both by papal bulls and royal decrees, the latter issued in 1608. However, its cultivation was permitted by a special law passed in 1614. By this same law the sale of tobacco to a foreigner was prohibited on penalty of death and confiscation of property. Other stringent measures were enacted in 1777 and 1784 which by their very severity defeated their own purpose. In 1775 the crop reached 701,750 pounds. Production was large enough to permit of exportation in 1836 (4,954,200 pounds), but by 1838 had declined to half that amount. The maximum crop was that of 1880, when 12,000,000 pounds were produced. The crop of 1897 reached 6,250,000 pounds.

The tobacco formerly went largely to Cuba, and a prohibitive customs duty in force in that island at present has greatly curtailed the acreage of the crop in Porto Rico in the last two seasons. Tobacco, while the third product of the island of importance in the foreign

trade, is relatively unimportant as regards the area devoted to its production. It is, however, of great importance, considered in the light of the possibilities of future extension. In the Departments of Arecibo and Ponce but 1 per cent of the cultivated area was devoted to tobacco in 1897.

Grazing of neat cattle and other live stock formed the chief industry of the colonists during the early history of the island, and it is still an essential part of the rural husbandry. Of the subsistence crops plantains, bananas, sweet potatoes, tanier, indian corn, rice, and cocoanuts have played important rôles in the development of the country over which the present soil survey was projected.

CLIMATE.

The area surveyed has a wide range of climatic conditions. While no complete records are available for the area, United States Weather Bureau stations are situated at Arecibo, Utuado, Adjuntas, and Ponce, where records have been kept for the last two or three years. The accompanying table shows the mean annual temperature for Arecibo and the mean annual precipitation for the district about Adjuntas, the other data being fragmentary. From these figures it will be observed that the climate is typically tropical, and that there is but little variation in the temperature from one month to another. Cool trade winds from the northeast lower the temperature considerably, and the island enjoys the reputation of being quite free from tropical diseases and fevers. As Ponce is on the southern coast, which is warmer and drier, it undoubtedly has the highest annual temperature of the entire area. Adjuntas, situated at an elevation of about 2,000 feet, is known as one of the coolest towns on the island. The normal temperature for Arecibo is 76.1° F.

December, January, and February are considered the coolest months, while August, September, and October are the warmest months. The precipitation as shown by the records at Adjuntas is least during February and greatest during April, June, July, August, and October. The rainfall for Adjuntas, as given in the accompanying table, is nearly 100 inches. Adjuntas and Utuado receive the greatest amount of rain because of their situation in the higher altitudes of the northern slope.

As compared with the northern side of the island, the southern side is quite dry, making irrigation necessary for the successful cultivation of most crops.

The moisture-laden trade winds blowing from the northeast pass over this area, causing a higher precipitation on the north side, and especially near the summits of the mountains. It is said that the mountains above Utuado and Adjuntas are frequently enveloped in clouds for months at a time, and that occasionally during the rainy

season the sun is not seen for weeks. Frosts probably never occur; at least killing frosts are unknown anywhere on the island.

Mean monthly and annual temperature and precipitation, 1900.

Month.	Arecibo.		Utuado.		Adjuntas.		Ponce.	
	Temperature.	Precipitation.	Temperature.	Precipitation.	Temperature.	Precipitation.	Temperature.	Precipitation.
	° F.	*Inches.*	° F.	*Inches.*	° F.	*Inches.*	° F.	*Inches.*
January	73.4	.....	[a]75.8	.....	67.4	2.58	[a]73.2	.....
February	73.0	0.87	.....	.....	67.5	.63	.....	.....
March	72.8	1.55	.....	0.45	67.9	1.62	[a]75.5	.....
April	75.2	5.38	.....	2.09	71.0	12.29	77.2	[b]2.00
May	77.0	3.16	.....	4.25	76.0	9.47	79.1	[b]7.90
June	78.0	7.43	81.2	8.34	75.0	18.92	[a]79.5	[b]6.10
July	78.2	4.84	.....	2.47	[a]75.8	11.06	80.5	[b]2.90
August	78.4	4.25	.....	3.45	79.5	21.42	80.4	3.76
September	78.5	3.59	.....	3.37	.....	4.61	.....	.....
October	77.4	4.79	[a]82.6	.....	79.8	10.94	.....	.....
November	76.6	6.28	80.1	8.11	80.1	2.82	.....	.....
December	74.9	5.89	74.3	1.08	79.1	1.54	.....	.....
Year	76.1	.....	.....	.....	.....	97.90	.....	.....

[a] Incomplete. [b] Normals.

PHYSIOGRAPHY AND GEOLOGY.

As the area surveyed passes over the three main physiographic regions of the island, it may be well first to briefly describe the physiography or surface relief of the entire island.

The greater part of the island consists of a series of mountain chains, composed largely of igneous and volcanic rocks, stretching in a general easterly and westerly direction, except in the northeast portion of the island. The mountain region is deeply carved and eroded and consists of a series of "cerros," or knobs, and elongated ridges from which rise numerous sharp peaks. Its altitude varies from less than 1,000 feet to about 4,000 feet.

Surrounding this central mountainous region is an area sloping gently to the sea, composed of coral limestone of considerable thickness. This area is of sedimentary origin and indicates that the whole island has been lifted about 1,000 feet above the sea in recent geologic time. This fringe of limestone is several miles wide in places, and where rock solution has been the most active agent of decay it presents the form of a table-land, but where erosion has been the most active this form has been lost and the surface consists of innumerable conical hills.

Lower down comes the coastal plain, with its low, rounded limestone hills, lagoons and swamps, and rich alluvial lands at the mouths of rivers.

In the area under consideration all these physiographic forms are

THE ALLUVIAL PLAIN NEAR ARECIBO, PORTO RICO, USED FOR SUGAR LANDS, WITH LIMESTONE HILLS IN THE BACKGROUND.

well developed, and so marked are the general characteristics of each that they stand out in bold contrast. The coastal plain in the area surveyed in the Department of Arecibo consists of low, rounded hills, the wide playa plain, and the coast lagoons and swamps. East of the Arecibo River and for a distance west of the city itself are low bars of sand dunes and beach sand. These bars and dunes, usually only a few feet in height, generally rest on a ridge of firmly cemented coral sand and fine gravel. They are covered with a coating of loose, incoherent coral sand, which is drifting southward, driven by the strong trade winds, which almost continually blow from the northeast. The city of Arecibo is built upon one of these low, rounded hills of firmly cemented coral sand; also the light-house and village east of the Arecibo River.

Just back of these dunes are generally found narrow swamps or lagoons, usually covered with thick clumps of mangrove bushes. These swamps are partly marine and partly alluvial in origin. West of Arecibo the swamps are of slight extent, and nowhere do they attain a width of more than one-third of a mile. East of the river the coastal swamps reach greater proportions, as will be seen from an inspection of the map. Certain parts of this swamp have been reclaimed and planted to sugar cane. More extensive reclamations have been planned at various times, but as the question of ownership of such tracts of land has not been definitely settled no considerable operations have been carried out. Much of this land, if properly drained, would make valuable sugar land, but in some localities thorough drainage would be an expensive undertakiug.

The playa plain includes an area of several miles situated on each side of the Arecibo River, with the greater development on the east side of the river. This plain, situated but a few feet above the sea, is remarkably even, with but few changes in elevation. It comprises all the valuable cane land near Arecibo, and probably represents a former estuarine deposit, laid down at a time when the land stood at a lower level than at present. The Arecibo River meanders through this plain, and only in times of the greatest floods, such as that which occurred during the hurricane of August, 1898, does the water cover any considerable portion of the plain. At the time of the hurricane the greater part of this plain was covered with several feet of water. The playa consists almost entirely of fine silt to a depth of several feet, and represents the slow deposition of such material in comparatively shallow, quiet waters. (See Pl. I.)

South of the alluvial lands near Arecibo are low, dome-shaped hills. Some of the lower ones have been nearly buried by the alluvial deposits of the river. Others rise symmetrically to a height of 100 feet or more. The rock of which these hills are formed is a soft white limestone that seems to weather uniformly, leaving few, if any, projecting

ledges. On top of the hills the soil is very shallow, while farther down it becomes deeper and richer. The thick mat of grass which usually covers these hills, together with the loose, porous rock below, prevents washing. West of Arecibo these hills extend down to the coast and are more numerous though not so symmetrical in form. From above they have the appearance of a rolling plateau. Prominent groups of these hills lie to the southeast of Arecibo, 4 miles directly south of the city in a great bend of the river and 1½ miles southwest of the city. (See Pl. II.)

Inland from the area of low, rounded limestone hills in the vicinity of Arecibo, and extending south for about 8 miles, is a large area of limestone, which, because of its greater elevation, rough, angular topography, the decided change in vegetation, a thick growth of trees and bushes, and the many bare rocks of chalky whiteness, stands out in marked contrast to the region to the north. The elevation of this material varies from about 200 feet near Arecibo to about 1,000 feet, where it rests as a mere capping upon igneous and volcanic rock along the Limon and Caiguantes rivers. These rivers seem to have adjusted themselves very largely to the old shore line, probably because it was a line of weakness, so that at present there is a noticeable valley in the vicinity of the line of contact. Where these rivers enter the Rio Grande de Arecibo they have cut deep gorges into the igneous and volcanic rock below, leaving an isolated capping of limestone at the junction of the Arecibo and Alonso rivers.

Along the northern border the hills are separated into parallel chains, frequently inclosing small, level valleys, but farther south the hills are more closely packed together and become a series of almost impassable barrancas or rock-walled canyons and pits. The steep-sided depressions show, on a tremendous scale, the enormous extent to which rock solution takes place under tropical conditions. They represent an almost endless series of great limestone sinks or basins formed by the dissolution of the softer layers of limestone by rain water. The water causes great underground cavities to be formed, the roofs of which finally break through and leave the perpendicular rock walls exposed. Standing on any of these hills capped with the harder stratum of limestone, the enormous size of the sink holes is at once realized. They are great basins with bare, perpendicular rock walls, frequently 100 feet deep, and sometimes reaching a depth of 200 feet. These basinlike depressions occasionally include small swampy spots, or a great spring may break forth in one side only to disappear in the opposite side. Some contain a few acres of fertile land. Frequently the streams and even large rivers that traverse this limestone country disappear altogether for considerable distances. In one instance the outlet at the bottom of one of these basins had become obstructed, and a small lake had been formed, in the midst of which were still growing cocoa palms and bread-fruit trees, while the empty buildings in the

A VIEW OF THE ALLUVIAL PLAINS, SHOWING THE LOW, ROUNDED HILLS OF THE ARECIBO SANDY LOAM AND THE LIMESTONE HILLS OF THE TANAMA STONY LOAM, PORTO RICO.

center, still in a good state of preservation, showed that the inundation had occurred within the last few years. The drainage of this region is mainly subterranean, and only two large rivers traverse it, the Arecibo and the Tanama, which carry a large part of the waters from the interior of the island. Both of these rivers flow in deeply cut canyons.

This broken table-land slopes gradually to the southward and its central region is most inaccessible and difficult to cross. Away from the military road only narrow trails traverse this country, and the question of transporting the products which may be grown in this region will always be a serious one. The trails, stony and rough, wind in and about the narrow ravines and frequently one has to cross five or six divides from 200 to 500 feet high in going a mile. Over such trails the native goes barefooted, either carrying his product to market on his shoulders or on the back of his little pack horse. Still, many people find a habitation in the limits of this hilly region, for the stony soils are comparatively fertile, although almost inaccessible and difficult to till. The rocks comprising this table-land consist of layers of hard and soft limestone of Miocene age. Along their margin these rocks contain many coral heads, often several feet in diameter.

On the south side of the island this limestone region has a very different appearance. The valley between it and the inner volcanic regions is much more distinct, as for example at Penuelas, but there is no sign of table-land and there are no pits or sinks. There are few trails and almost no houses. The soils are very shallow and, owing to the arid conditions that exist there, they are at present almost worthless except for pasturage during the wet season.

In point of area the central or igneous and volcanic region is the most important, as it represents more than half the area surveyed. This picturesque region, which is enormously eroded, slopes toward the north. In the valley at Utuado the altitude is about 600 feet, while about 10 miles south, above Adjuntas, where the military road crosses the divide, the altitude is about 2,400 feet, according to barometric readings by Mr. Herbert M. Wilson.[a] West of this point, on the border of the area surveyed, Mount Guilarte, the second highest peak on the island, rises over 1,000 feet higher. South of the divide the descent is very rapid, the distance to the seacoast being only 15 miles in an air line from Mount Guilarte.

The divide is but 11 miles from Ponce, while it is about 25 miles from Arecibo. The position of the divide, so far to the south side of the island, may be accounted for by the fact that the trade winds, which blow continually from the northeast, are robbed of their moisture before or while passing over the divide, and therefore there is a

[a] Water resources of Porto Rico (1900).

greater rainfall on the north side of the island. The heavier rainfall has produced greater erosion and slowly shifted the divide southward. On the north this ridge slopes gently, with numerous knobs and elongated ridges, to the valley lying at the junction of the Alonso and Arecibo rivers. Valleys similar to this are frequently called "parting valleys," for usually at the junction of the limestone table-land and the central-mountain region a well-defined valley is observed. It is along the junction of these two physiographic regions, also, that the main drainage rivers have developed the lateral tributaries which have formed them.

Throughout the central mountain region there are many rapid streams. The amount of rainfall and conditions of temperature are such that the rate of erosion is tremendous. At Utuado the erosion forms are very beautiful, and an accurate relief model of the valley and surrounding mountain slopes would appear almost as if constructed after someone's fancy. The rocks in this vicinity are a coarser-grained granite that has weathered more rapidly than the surrounding country, the valley being the result. The rate of erosion of this rock at the lower elevations has been greater than the rate of weathering, as shown by the sandy character of the soils, which are of little agricultural value. On the higher elevations, where weathering has been more rapid than erosion, the characteristic soils are deep reddish clay loams and tenacious red clays. Such soils are best for coffee, and throughout this region coffee plantations may be seen on every hand.

Fine examples of the rocks of the central mountain region may be seen along the military road from Arecibo to Ponce, where they are used for road ballast. Many volcanic conglomerates, containing bowlders several feet in diameter, were noticed, as well as extensive areas of volcanic tufa. South of the divide, the dividing ridge being only 11 miles distant in an air line from Ponce, the slope is much steeper, and the streams are correspondingly much smaller and in the upper part of their valleys are rapidly eroding their channels. Owing to the semi-arid conditions of this region irrigation is necessary, and the streams either dry up or become nearly lost in the sands and gravel in their lower reaches. On the southern portion of the island the limestone foothill region, while not so prominent as on the northern slope, forms a considerable table-land, similar in many respects to that found on the northern side of the island, but not so broken and dissected, nor is it situated at so great an elevation above the level of the sea. There also occurs an area of low, rounded hills, but they lack the symmetry of the hills around Arecibo. South of the limestone table-land, in the vicinity of Ponce, a considerable playa plain has been developed at the mouth of the Portugues River. This plain forms the sugar lands of the south coast and is quite similar in many respects to that which

occurs in the vicinity of Arecibo, the chief distinction being the more sandy texture of the soil.

Four and one-half miles southwest of Ponce there is a large lagoon much like those on the north coast. It is quite deep and is protected from the sea only by a bar of sand. Along the coast to the south and east of Ponce there are some areas of low-lying alkali land. The abundance of marine shells in this land and in the subsoil of much of the land in the vicinity of Ponce would indicate that the whole plain was built up by deposits laid down in shallow salt water, just as they are now being laid down in the large lagoon just mentioned.

SOILS.

As the present survey includes a strip passing through all the geological regions and having all the various climatic conditions of the island, it is thought that the soils mapped include nearly all of the important types of the island. They embrace those derived from the slight superficial weathering of coral reefs and sands, from the deep weathering of hard, igneous trap rocks, and from the accumulation of alluvial deposits along the Arecibo and other rivers. The appended table shows the approximate areas of the different soil types.

Areas of different soils.

Soil.	Acres.	Per cent.	Soil.	Acres.	Per cent.
Tanama stony loam	41,680	19.7	Ponce sandy loam	6,550	3.1
Adjuntas clay	29,890	14.2	Penuelas adobe	6,680	3.2
Utuado sandy loam	25,100	11.8	Portugues adobe	4,010	1.9
Arecibo loam	17,700	8.4	Arecibo sandy loam	2,690	1.3
Pastillo loam	16,040	7.6	Coral sand	2,620	1.2
Portugues stony loam	15,600	7.4	Ponce loam	2,480	1.2
Alonso clay	13,690	6.5	Vivi sandy loam	1,060	.5
Arecibo silt loam	8,960	4.2	Riverwash	970	.5
Utuado loam	7,880	3.7	Total	211,180	
Arecibo sand	7,580	3.6			

CORAL SAND.

This type consists of coral and shells ground up by the action of the waves and mixed with a small amount of quartz sand brought down by the rivers and driven inland by the winds. On the south side of the island this sand covers several square miles. The areas are low lying, and attain their greatest elevation (8 or 10 feet) within 75 yards of the coast, sloping gradually inland from this point. On the north side the areas of this soil are much smaller. The sand here has drifted up in the form of dunes, beneath which cemented coral sands were found in several places.

On account of the loose, incoherent nature of this soil it does not contain alkali except in the low-lying places on the south coast, where the water table comes close to the surface.

Several areas of this soil have been planted to cocoanut trees, which are quite resistant to salty conditions of soil. Though in some places the roots of the trees are even washed by the sea, the trees grow fast and begin to fruit in five years. This type is one of the best for cocoanut plantations, and of but little use for anything else in a commercial sense. In a few places fishermen have cleared small areas of Coral sand within 100 yards of the sea and planted them in plantains, bananas, and sweet potatoes for home consumption. The latter were said to do fairly well in favorable seasons. The land is valued at less than a tenth of the value of the sugar-cane lands.

The following table gives the mechanical analyses of the Coral sand:

Mechanical analyses of Coral sand.

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
6499	1 mile E. of lighthouse at Arecibo.	Coral sand, 0 to 36 inches.	12.90	1.53	40.10	45.36	9.64	0.75	0.59	2.45
6588	3 miles SE. of Ponce.	Drifted incoherent sand, 0 to 36 inches.	1.02	2.98	16.74	27.50	39.70	5.34	2.96	4.14
6586	3 miles SW. of Ponce.	Coral sand, 0 to 24 inches.	.86	3.60	22.80	25.00	26.40	7.90	7.60	6.46
6587	Subsoil of 6586....	Coral sand, 24 to 36 inches.	.65	3.60	20.16	22.20	26.10	8.70	8.60	10.44

ARECIBO SAND.

Arecibo sand consists of medium-grade sand having a depth of at least 3 feet, with little or no difference in character or in appearance between the soil and subsoil. It is loose and incoherent and easily cultivated, but this open character makes crops planted on it very liable to damage from drought.

The Arecibo sand varies considerably in color, most often being red or white, frequently occurring in shades of brown, yellow, gray, and even black. The gray and black sands are usually closely associated with the white, and undoubtedly owe their color to a mixture of white with a greater or less quantity of thoroughly decomposed organic remains. The red sand possesses a soft feel and consists of rounded grains of coral, the soil and subsoil being the same. The brown and yellow sands are similar in composition and are mixtures and varia-

tions of the red and white sands. The red soil is usually considered better than the other colors of this type.

The largest areas of Arecibo sand are situated southwest and west of Arecibo. Small patches are also found southeast of the city and a few others in the limestone valleys to the southward. The only area of importance consisting of white sand lies north of the Lares road, 3 miles west of Arecibo. It is made up principally of pure quartz grains, and it is for the most part devoid of vegetation. These soils are either areas of wind-blown sand which has drifted inland from the seacoast or, in some cases, relics of former beaches, constructed at a time when the sea stood relatively much higher than it does at present.

In the small inclosed valleys occupied by this formation the surface is comparatively level, but with some gentle undulations, while to the west and southwest of Arecibo the sand occurs as a covering, a few feet in depth, over rolling hills and valleys underlain by whitish limestone.

Many different crops are grown on these soils, with varying results. Small areas of gondules, sweet potatoes, corn, beans, cassava, and tobacco were observed. A small amount of fruit is also grown, consisting of cocoanuts, bananas, plantains, papaya or papaw, pineapples, etc. The red sand may be adapted to orange culture, although as yet no attempt has been made to grow this fruit on a commercial scale. To the west of Arecibo this soil produces fair crops of Guinea grass.

The brown and yellow sands are used for much the same crops as the red sand. In general the Arecibo sand, with proper fertilization, might produce good crops of pineapples, for it closely resembles—especially in the white phase—the famous pineapple lands of southern Florida; but as yet very little attempt has been made to grow this fruit.

The following table contains the mechanical analyses of samples of the red and gray sands:

Mechanical analyses of Arecibo sand.

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
6485	3¼ miles SW. of Arecibo.	Dark medium sand, 0 to 36 inches.	0.53	0.20	14.73	48.86	27.93	3.92	2.66	0.74
6483	1 mile SW. of Arecibo.	Red coral and quartz sand, 0 to 12 inches.	.82	.00	10.31	32.75	43.85	8.22	3.84	1.85
6484	Subsoil of 6483	Red coral and quartz sand, 12 to 36 inches.	.32	Tr.	8.29	26.66	48.53	8.27	4.22	3.63

RIVERWASH.

The Riverwash generally consists of a coarse grade of sand, but often it is mixed with varying amounts of coarse and fine gravel. There is little difference between the soil and the subsoil.

The only areas of this soil type occur along the river in the vicinity of Arecibo.

The soil is derived from the deposition of sediment by the river at times of flood, and is liable to overflow during heavy rains at almost any season of the year. For this reason it is not of much agricultural value. Very little attempt is made to cultivate it, and it is covered with a sparse growth of grass, which affords some pasturage.

ARECIBO SILT LOAM.

The Arecibo silt loam, which is one of the most important agricultural soils of the area, consists of a heavy, rich brown silty loam, having a depth of at least 3 feet, and in many cases a depth exceeding 10 feet or even 15 feet. Little difference can be detected between the soil and subsoil to a depth of 36 inches, except that in the lower depths it is usually of a slightly lighter color. When in a moist condition it is of a dark brown, but the surface, after a period of several weeks without rain, becomes decidedly lighter in color. In some localities occasional small bands of coarse sand are found, rarely exceeding a few inches in thickness, and occasionally scattered pebbles are seen on the surface. Along the Arecibo River there are in places shallow deposits of fine or even medium sand, never of sufficient depth to impair the soil for the growing of sugar cane.

The Arecibo silt loam is found south of Arecibo on both sides of the river, occupying the greater part of the plains region of the north coast and extending on the west side to the foot of the limestone hills and on the east side merging into the areas of swamp land or reaching back to the foot of the rounded and sometimes to the angular limestone hills.

This soil has generally a very level, flat surface, but at times this gives way to gently rolling topography. There are a few low terraces, but it is doubtful if in the entire area an elevation greater than 30 feet is anywhere attained.

The Arecibo silt loam is rarely overflowed, except at the times of severest hurricanes. During the hurricane of August, 1898, a large portion of the area was covered with water to a depth of several feet, and a small village located within it was swept away. When the river overflows this land and then gradually recedes there is a decidedly beneficial effect, but in periods of such high water as that of 1898 large tracts of land are completely ruined by the deposit of coarse sand, which often accumulates to a thickness of several feet. On account of the small quantity of clay in this soil it drains readily for a

heavy loam, although it is necessary to have open ditches at short intervals to carry off the surplus water during times of heavy rainfall. During the wet season these ditches become filled, and the soil is so thoroughly saturated that even slight showers bring the water table near the surface.

The Arecibo silt loam has been formed by the slow accumulations of sediments carried down from the interior mountain region by the river and deposited in comparatively quiet, shallow waters, when the land was depressed below sea level. The soil is the result of the superficial weathering of this extensive deposit of silt, mixed with the vegetable matter that has accumulated from year to year from the growing of sugar cane.

There is a phase of this soil occurring on the south side of the island which consists of about 36 inches of a dark gray silt loam. The areas in this part of the island have been formed in the same way as the more typical areas, but they are lower lying and are apt to be salty and unfit for the cultivation of sugar cane. In a few instances, too, the subsoil was noticed to be slightly heavier than in the typical section. These areas are covered with mangroves and other salt-resisting trees and by coarse salt-marsh grasses and are used for pasture. Drainage and the reclamation from present alkali conditions, and in some cases the construction of a dike along the sea front to keep out the sea water at times of severe storms, would convert these areas into valuable sugar-cane lands.

The Arecibo silt loam is the most valuable soil in the unirrigated district for the production of sugar, to which crop it is almost exclusively devoted, and the sugar industry that has developed on it during the last three hundred years is considered one of the most important on the island. The yield per acre ranges from 30 to 60 tons, but the average is perhaps 40 tons. This yield is equaled only on the Ponce loam, which is an irrigated type, the cane from which has a higher sugar content.

Tobacco is grown to a limited extent on the more sandy portions of this soil along the upper course of the river. The quality of the leaf is said to be very good, though not equal to that produced on the Vivi sandy loam. A yield of 800 pounds per acre is considered high, and the average yield does not far exceed 600 pounds per acre.

Plantains and bananas do very well on this soil, but all crops are of minor importance at present in comparison with the great staple, sugar cane.

Records show that sugar cane has been grown on some of this land for more than three hundred years; and though the yields have decreased, it is said that most of it is in excellent condition and seldom needs "resting," the method of recuperating the soils followed on the island.

This land commands a high price on account of the large yield it produces, and practically none of it is for sale, as all of the large planters endeavor when possible to increase their own holdings.

The silty character of this soil can readily be seen from the following mechanical analyses:

Mechanical analyses of Arecibo silt loam.

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
6575	2½ miles W. ¾ mile S. of Ponce.	Light gray silty loam, 0 to 14 inches.	2.45	0.26	0.60	0.50	1.76	9.00	73.24	13.24
6475	2 miles S. of lighthouse at Arecibo.	Rich dark-brown silty loam, 0 to 12 inches.	1.98	.39	.55	.55	10.81	10.81	53.06	24.07
6577	½ mile E. of Port Ponce.	Dark silty loam, 0 to 36 inches.	1.93	.56	.80	1.70	12.62	9.60	44.76	29.72
6477	4 miles S. of Arecibo.	Rich dark silty loam, 0 to 12 inches.	2.31	.69	2.34	1.79	6.30	10.05	48.62	29.87
6478	Subsoil of 6477.....	Rich dark silty loam, 12 to 36 inches.	1.15	.95	2.46	1.83	11.00	10.95	45.58	26.67
6476	Subsoil of 6475.....	.....do.....	1.13	.31	.79	.46	4.03	7.27	55.28	31.06
6576	Subsoil of 6575.....	Dark loam, 14 to 36 inches.	.24	.60	.54	.40	1.96	5.90	55.68	34.32

ARECIBO SANDY LOAM.

The Arecibo sandy loam consists of a heavy red sandy loam with a depth of 10 inches, underlain to a depth of 36 inches by a clay loam that is rather tenacious and yet contains a considerable amount of medium-grade sand. When cultivated it appears rather loamy on the surface, but when it has lain idle for some time and is covered with a growth of grass it becomes hard and baked, giving one the impression of a much heavier soil.

It occupies some of the valleys occurring among the outlying limestone hills. These valleys are level or gently rolling, with elevations ranging from 30 to 100 feet above sea level, and are nearly all surrounded by hills possessing soils of a decidedly different character. On account of the sandy nature of the soil it is naturally well drained. The Arecibo sandy loam has probably been derived from the wind-blown or beach sand mixed with the residual products of the surrounding limestone hills.

Usually the areas of this soil are settled by the poorer classes of people and used to a limited extent for growing truck, fruit, and other

minor crops, such as beans, corn, sweet potatoes, and gondules. Some tobacco is at present grown, but it does not compare in quality with that grown on the alluvial soils in the mountain districts. In the area east of the river, in the vicinity of Santa Ana, some light crops of sugar cane were observed. This soil is much better adapted to pasture, fruits, principally plantains, bananas, cocoanuts, and garden and truck crops than to such crops as cane and tobacco.

The following table contains the mechanical analyses of a typical sample of the soil and subsoil of this type:

Mechanical analyses of Arecibo sandy loam.

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
6473	4 miles SW. of Arecibo.	Red sandy loam, 0 to 12 inches.	0.46	0.00	4.51	18.39	50.83	6.19	6.39	13.83
6474	Subsoil of 6473.....	Stiff sandy clay loam, 12 to 36 inches.	.22	.43	3.66	14.13	41.92	5.80	8.54	25.24

ARECIBO LOAM.

The Arecibo loam consists of a black, waxy, tenacious loam to a depth of from 6 to 12 inches, depending somewhat on the character of the surface where the soil is formed. East of Arecibo, near the ocean shore, this black loam has a depth of at least 12 inches, but on the rounded limestone hills as well as in the large area south of Esperanza the soils are shallower and contain a large number of fragments of the parent limestone. The subsoil is a tenacious yellow loam, which in its lower depths becomes more sandy and contains increasing amounts of loose limestone fragments. In the large area south of Esperanza the subsoil passes at about an average depth of 18 inches into a rotten mass of limestone fragments. In the large area lying along the coast west of Arecibo the soil is shallow, underlain by broken limestone, and with fragments of the parent rock scattered thickly on the surface. The area of this soil found east of the Arecibo River, which is probably in a better state of cultivation and of greater agricultural value than any of the others, has a level or gently rolling surface. West of Arecibo the surface is also rolling, and the elevation ranges from 50 to 150 feet above sea level. South of Esperanza and in a similar area east of the Arecibo River the surface is rough and broken and elevated several hundred feet above the sea. In these latter areas

the surface is so rough and irregular that the soil can not be utilized to any great extent in the cultivation of the ordinary crops.

From the tenacious character of the material forming this soil a swampy condition is found wherever the surface is not hilly or uneven. East of the Arecibo River, near the shore, many small swamps occupy the slight depressions, and somewhat similar occurrences are met with along the trails in the rough broken areas farther south, which during the wet season become well-nigh impassable.

Near the seacoast this soil has been derived from a soft gray limestone of comparatively recent geologic age. Farther north, in the limestone hill country, it is derived from the chalky white limestone of Miocene age. The latter is frequently spoken of as coral limestone on account of the great number of coral heads found in it.

This soil type is spoken of as "fat land." It is well adapted to pasturage, and in all areas, except where the hills are rough and rocky, is always covered with a thick mat of rich, green grass. A small amount of tobacco is grown on this soil. No attempt, however, at growing tobacco on a large scale, has been made, and it remains to be seen whether extensive tobacco growing can be profitably carried on. Fruits do fairly well, and in the more hilly portions, where the soil is deep, a few orange trees were in fair condition. Where the soil is shallow and rests on solid rock the growing of oranges on a commercial scale should not be attempted. Bananas, plaintains, and coffee, together with gondules, sweet potatoes, and the minor produce crops, are raised to a considerable extent, but always in small patches and with never any attempt at cultivation on a large scale.

The mechanical analyses of representative samples of this soil type are given below:

Mechanical analyses of Arecibo loam.

[Fine earth.]

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
6471	3 miles W. of Arecibo.	Dark loam, 0 to 8 inches.	4.98	6.88	10.92	11.14	20.09	11.01	26.24	12.94
6469	1½ miles E. of lighthouse at Arecibo.	Black, heavy, waxy loam, 0 to 18 inches.	2.33	1.65	9.50	8.53	20.50	9.46	24.86	24.46
6472	Subsoil of 6471....	Yellow loam, 8 to 18 inches.	3.29	6.66	9.13	9.73	17.72	10.22	31.19	14.53
6470	Subsoil of 6469....	Stiff yellow clay loam, 18 to 36 inches.	.29	1.39	8.09	8.45	17.98	5.92	19.85	37.42

ALONSO CLAY.

The Alonso clay consists of a dark, purplish clay loam, having a depth of from 8 to 36 inches and containing a varying amount of pebbles and sometimes large bowlders. Where the soil is deepest there is a tendency to become more clayey with depth. The subsoil is a heavy tenacious loam of the same color as the soil, resting on a purplish igneous rock of the character commonly called trap rock. In some areas the underlying rock comes to within 15 inches of the surface. The soil has a tendency to form clods when cultivated and to bake upon drying.

Three different areas of this type occur within the limits of the survey. The largest lies along the Limon and Arecibo rivers, the next in extent about 10 miles southeast of Adjuntas, and the third about 4 miles to the southwest of that city.

The Alonso clay is a residual soil derived from the disintegration and decomposition of a dark, purple-colored igneous rock. Fragments of this rock are often found in the soil and subsoil. Frequently these fragments occur as bowlders. These are of the interesting form known to geologists as "bowlders of disintegration," which are believed to be formed from solid blocks of rock by the process of weathering in concentric rings.

There is a wide difference in the agricultural value of the different areas of this soil. The area along the Limon and Arecibo rivers is at present used mainly for pasturage, while the area between Adjuntas and Ponce is found upon steep slopes and is shallow, and with the scanty rainfall is of little value. In a few favored places bananas, plantains, and coffee are produced. The smallest area, that lying southwest of Adjuntas, is the most important agriculturally. The soil is deep and fertile. A large part of the area is in coffee and the trees appear to be healthy and vigorous. The yield reaches 400 pounds of dried coffee per acre, which is not exceeded by any soil type in the area and is equaled only by the Adjuntas clay. Orange trees of large size are also seen, and these are for the most part free from diseases or scale. With the exception of some orange trees on the Adjuntas clay, those on this soil were the best seen in the area. Bananas and plantains are also important crops on this soil. The yield ranges from 50 to 200 bunches per acre, but the bunches are not so large as on the lowlands. The soil of the large area on the Limon and Arecibo rivers appeared very similar to the soil of the tobacco lands of Cayey, and while no attempt to grow tobacco has been made it would seem that the soil is well adapted to that crop.

The following table gives the mechanical analyses of the soil and subsoil of this soil type:

Mechanical analyses of Alonso clay.

[Fine earth.]

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Course sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
6479	Near junction of Alonso and Arecibo rivers.	Dark heavy loam, 0 to 8 inches.	3.64	4.55	8.11	8.63	17.90	19.05	18.68	22.34
6560	6 miles N. 1 mile W. of Ponce.	Loam, 0 to 28 inches.	1.55	5.78	3.20	2.62	8.66	10.94	35.22	33.30
6481	12 miles S. of Arecibo on Caretera.	Dark heavy loam, 0 to 8 inches.	2.73	.34	3.66	3.98	14.46	10.35	31.78	35.41
6559	6½ miles N. 2 miles W. of Ponce.	Dark loam, 0 to 14 inches.	1.77	3.10	3.34	1.84	5.14	6.40	38.40	40.86
6558	3 miles SW. of Adjuntas.	Dark loam.....	1.93	.26	1.08	1.14	5.40	8.72	30.74	51.90
6482	Subsoil of 6481.....	Dark clay loam, 8 to 36 inches.	.98	.32	2.02	2.79	13.13	7.11	41.35	33.16
6480	Subsoil of 6479.....	Dark clay loam, 8 to 30 inches.	1.67	.30	1.72	1.19	4.37	5.76	32.52	53.92

UTUADO LOAM.

The Utuado loam consists of a mellow dark-brown or yellow loam, having an average depth of 8 inches. The soil is generally free from stones and is underlain by loamy subsoil, yellow in color and differing slightly in texture from the surface soil.

The type occupies the low, rounded slopes along the Arecibo River and the rolling, mountainous land a short distance south of Utuado. It ranges in elevation from 100 to 1,200 feet above sea level. The soil is residual, having been derived from the slow decomposition of volcanic and igneous rocks.

The greater portion of this soil is used as pasture land, for which it serves fairly well. In some favored places coffee is grown, and the trees were apparently in a healthy condition. On the protected slopes and under proper condition of shade the cultivation of this crop might be profitably carried on, for the soil is deep and loamy and easily penetrated by roots.

The mechanical analyses of the soil and subsoil of this type are given below.

Mechanical analyses of Utuado loam.

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
6491	8¼ miles N. of Utuado.	Dark-brown loam, 0 to 7 inches.	2.47	1.73	4.77	4.55	16.19	10.62	27.87	33.63
6492	Subsoil of 6491.....	Light-yellow loam, 7 to 36 inches.	.58	1.08	3.14	5.89	20.04	9.78	29.76	30.21

UTUADO SANDY LOAM.

The Utuado sandy loam is a coarse sandy loam of a grayish-yellow color, grading into a grayish sandy loam. This gradually passes into the coarser material of the underlying granite and other rocks from which it is derived.

But one body of this soil is found in the area surveyed, and this occurs in the mountainous region about Utuado. The town is situated in the northwestern part of this tract, which stretches about 5 miles south and east and passes beyond the limits of the survey.

The surface of the Utuado sandy loam consists of furrowed and gullied hills and mountains. These have an elevation ranging up to 200 feet above the intervening V-shaped valleys. In few of the soils mapped in this survey has erosion been carried on to so great an extent as is seen in this formation. When the sun is shining on the mountain slopes in such a manner as to accent their eroded character, they are seen to consist of almost an endless series of narrow necks and tongues, which rise to higher necks and tongues until the main dividing ridge is reached. These connecting necks are very narrow, and the intervening slopes are in places inclined at an angle of more than 50°. The trails which cross the ridges follow these necks of land, and in many cases so narrow are they that the road must be propped up by posts and small tree trunks to prevent its being washed away by the heavy, dashing rains.

On account of the steepness of the slopes these soils are comparatively dry, even in periods of excessive rainfall. In fact, the drainage is so thorough and so rapid that a short period of drought is liable to injure the crops. At the time of the survey crops of beans, corn, and sweet potatoes were suffering for rain, although but two weeks had elapsed since the soil had been thoroughly drenched.

This soil is residual, being derived from an underlying coarse-grained gray granite and similar igneous rocks. So rapid is the erosion that the surface soil does not accumulate and become thoroughly

decomposed; hence it bears a close resemblance to the rocks from which it is derived. The sand which forms the greater part of this soil is coarse and angular, being made up largely of quartz grains and undecomposed feldspar.

The Utuado sandy loam has little natural fertility, which is soon exhausted by the present methods of farming. A few coffee plantations lie in the area, and the trees in favored locations appear to be thrifty, but on account of its shallowness and its coarse, sandy texture this soil type is not well suited to coffee culture. Sweet potatoes, beans, corn, and other minor subsistence crops are grown in the area, but not to a great extent. In some places these crops are seen growing on slopes of an angle of inclination exceeding 50°, but such locations are too dry to produce good crops, aside from the difficulty of cultivation and the damage from soil washing and landslides.

The area of this soil has for some time been deforested and is now grown up with a coarse grass, closely resembling the broom sedge commonly found in the Southern Atlantic States. On account of the steepness of the slopes and the rapid rate at which erosion takes place this soil should not be cultivated to any great extent to crops that expose the soil to the heavy rains of the wet season. It would seem that if systematic forestry were introduced much of the area which is now idle waste land might be converted into valuable timber land.

The following table shows the sandy nature of these soils:

Mechanical analyses of Utuado sandy loam.

[Fine earth.]

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
6493	2 miles W. of Utuado.	Coarse sandy loam, 0 to 7 inches.	0.74	19.96	19.52	9.43	14.47	9.43	19.18	8.47
6494	Subsoil of 6493....	Coarse sandy loam, 7 to 24 inches.	.25	18.32	20.88	9.49	15.41	11.44	16.72	8.24

VIVI SANDY LOAM.

The Vivi sandy loam consists of a friable brown sandy loam, having an average depth of 10 inches and underlain by a darker-colored sandy loam of a peculiar soft texture. This soil resembles in a way the Utuado sandy loam, being made up of much the same character of material, reworked and ground finer by water action. In some areas a slight variation in texture occurs, the soil losing its loamy character

and becoming a fine, mellow sand. In other areas the subsoil is slightly heavier than in the typical sections.

This type is found only to a limited extent. The largest and most important area lies along the Arecibo River west of Utuado, while smaller scattered areas occur in small valleys to the southwest of that town. The latter areas are usually surrounded by mountains that rise to a height of 1,000 feet above sea level. The position of this type makes it subject to occasional overflow during the rainy season, and loss of crops sometimes occurs from this cause. The surface is usually level, although there were noticed some well-defined terraces a few feet high sloping up toward the mountains. The soil has been formed by wash from the hillsides and by the deposition of sediment by the streams along which it occurs.

This soil type is more fertile and possesses a much higher agricultural value than the Utuado sandy loam. It is used to some extent for the production of sugar cane, which yields from 10 to 20 tons per acre, and a part of it is kept in pasture. The main value of this land, however, is its adaptability for growing a superior type of cigar wrapper and filler tobacco. For this crop the Vivi sandy loam holds first place among the soils of the area. The areas in the higher mountain valleys are said to be very similar in character of soil and their relation to drainage and climatic conditions to the valuable tobacco soils about Comeiro. The yield of tobacco on the Vivi sandy loam ranges from 600 to 800 pounds per acre. The tobacco industry around Utuado is being developed principally on this soil.

The following table shows the mechanical analyses of representative samples from the bottom lands near Utuado:

Mechanical analyses of Vivi sandy loam.

[Fine earth.]

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
6495	½ mile W. of Utuado.	Sandy loam, 0 to 10 inches.	0.72	0.35	6.77	18.37	41.70	16.89	11.49	4.73
6497	1 mile N. of Utuado.	Yellowish-brown sandy loam, 0 to 10 inches.	.89	.70	10.02	16.91	28.37	11.73	18.39	12.90
6496	Subsoil of 6495....	Sandy loam, 10 to 36 inches.	1.00	.44	4.15	7.39	28.24	19.58	21.95	17.79
6498	Subsoil of 6497....	.....do.....	.87	.60	5.65	8.11	24.81	15.08	27.34	18.83

ADJUNTAS CLAY.

The Adjuntas clay, locally known as "the red-clay land," is a pink, red, or dark-brown clay 3 to 8 inches deep, underlain by a red or pink clay subsoil 20 inches or more in depth. In some areas landslides and road cuts show the soil covering to be as much as 15 feet in thickness, grading into the decomposed volcanic and igneous rock which underlies the whole area. The difference in color is due to the state of weathering and the presence of more or less vegetable matter in the soil, the darker brownish soils being found chiefly in the virgin lands or at the base of the slopes where there has been an accumulation of humus in the washings.

This soil type occupies one very large area around Adjuntas, extending across the area surveyed from east to west and lying along the western boundary for some distance north of Utuado. There are also two small areas northeast of the latter town.

The topography of the Adjuntas clay is rough and mountainous, with many steep slopes and deep, narrow valleys. There is therefore much less trouble from lack of drainage than from the washing of the soil. Under the torrential downpour of tropical storms the erosion is very severe, and great care has to be used in the handling of this soil in the exposed situations.

In origin this soil is residual, being formed by the breaking down and decay of the igneous and volcanic rocks that form the backbone of the island. This disintegration has taken place to considerable depths, as shown by the soil mantle, in some places reaching a depth of 15 feet, the rock often showing decay beneath this.

The Adjuntas clay is next in importance to the valuable sugar lands of the coastal plain region, being the principal soil upon which coffee is grown. The yield upon the richest lands—those containing the most humus—reaches 400 pounds of the dried bean per acre. The product on this soil type is also the best in the area, the price for the better grades being $3 per 100 pounds higher than for the coffee grown on the Tanama stony loam, for instance. Many coffee estates are located in this area, some of which have large tracts under cultivation. The majority of owners, however, were left in such poor circumstances as a result of the hurricane of 1898 that they have been unable to replant or to keep up their estates. In many cases the ferns and vines have completely covered the few remaining trees.

Throughout the area a few well-regulated estates show what can be done with care, but only persons with means, who can put estates in good condition and wait for returns until the trees come into full bearing, can expect to make much of a success in the cultivation of this crop at the present prices.

Several of the coffee estates have orange trees here and there among the coffee trees and along the trails. They are usually of fair size,

well laden with fruit, and superior to the trees seen in any other locality in the area, with the exception of those found on the area of Alonso clay to the southwest of Adjuntas.

On the completion of the military road, giving good and easy communication with Arecibo and Ponce, the Adjuntas clay adjacent to the main road will undoubtedly offer some of the best opportunities for citrus fruit cultivation to be found in the area. Large quantities of bananas, plantains, Yantia, and malanga are grown to supply the laborers of coffee estates and the people of the south side of the island, where it is in many places too dry for the cultivation of these food crops.

The following table shows the mechanical analyses of samples of Adjuntas clay:

Mechanical analyses of Adjuntas clay.

[Fine earth.]

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
6556	¼ mile W. of Adjuntas.	Dark-colored clay loam, 0 to 18 inches.	3.17	0.66	1.40	1.50	7.46	8.90	38.62	41.04
6589	8 miles N., 3 miles W. of Ponce.	Clay, 0 to 6 inches..	1.36	.16	.52	.46	2.22	3.48	35.80	56.64
6555	3 miles N. of Penuelas.	Light-colored clay, 0 to 36 inches.	.64	.74	1.12	.78	3.04	4.34	32.56	57.84
6557	Subsoil of 6556.....	Red clay, 18 to 36 inches.	1.10	.30	1.50	1.70	6.60	8.46	52.30	28.94
6590	Subsoil of 6589.....	Clay, 6 to 36 inches..	.91	.00	.28	.40	1.94	3.70	35.20	57.52

PORTUGUES ADOBE.

The Portugues adobe is a heavy dark-brown loam resembling adobe, underlain by material of a somewhat similar character, but of a lighter color, which gradually grades into a light yellow as the depth increases. The soil is formed from the decomposition of limestone, a few fragments of which occur in some areas. These are a more prominent feature of the area west of Ponce, where a light-colored phase of this type occurs. Owing to its heavy, plastic texture, the soil is very difficult to till.

The Portugues adobe occurs only on the south or semiarid side of the island, in a number of areas of regular outlines. It occupies valleys and gentle slopes in the limestone hill region, partly above present irrigation systems. The greater part of the higher-lying areas are

very uneven, so that even if water could be brought to this level irrigation would be a costly operation.

Previously to the hurricane of 1898, which destroyed many mills and cane fields, leaving some of the planters in such circumstances that they were unable to rebuild their mills or replant their fields, the lands under irrigation were mostly devoted to cane. Since that time, however, these lands for the greater part have been used for pasture, to which use the lands above irrigation have always been put. They are now being gradually replanted, and it is only a question of time when they will once more be cane fields. With sufficient moisture, good crops are raised, the cane carrying a high per cent of sugar. This soil ranks fourth of the soils of the area, and third of the irrigated soils, in the production of cane. The yield varies from 15 to 30 tons per acre.

Tobacco is also grown on this type. The quality is said to be very good. The leaf is used chiefly for the manufacture of cigarettes. One field of about 30 acres was seen on the light-colored phase of soil west of Ponce. This was under irrigation and had been planted to tobacco for the last three years. Several crops were harvested from each planting, and the leaf secured was of a type suitable for cigar wrappers and fillers. The proprietor of this tract said he should abandon the growing of tobacco with the end of the present season and put the land again in sugar cane.

Bananas are also grown on this type, and where the land is level enough to permit irrigation and the supply of water plentiful the yields are very satisfactory. As many as 700 bunches have been gathered from 1 acre in a single year.

The following table shows the texture of typical samples of the soil and subsoil of this soil type:

Mechanical analyses of Portugues adobe.

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
6580	2½ miles W., ¾ mile S. of Ponce.	Dark-brown loam, 0 to 16 inches.	0.88	0.46	1.80	2.00	7.10	12.80	42.66	32.40
6582	1 mile W., ¼ mile N. of Ponce.	Heavy dark-colored loam, 0 to 17 inches.	2.17	1.60	2.80	2.20	7.00	11.68	40.46	34.26
6583	Subsoil of 6582.....	Light-brown heavy loam, 17 to 36 inches.	.75	.46	1.56	1.34	3.12	6.66	49.24	37.02
6581	Subsoil of 6580.....	Light-brown loam, 16 to 36 inches.	4.61	1.14	2.62	1.82	6.00	11.56	38.12	38.74

PORTUGUES STONY LOAM.

The soil of the Portugues stony loam is a dark loam of an average depth of 14 inches. Intermingled with the fine material is from 20 to 60 per cent of angular stones, the whole resting on a bed of fragments of partly decomposed volcanic and igneous rock. The depth of the soil mantle varies greatly, being shallow on the hills and steeper slopes and much deeper along the northern and southern borders of the area, where, too, the content of rock fragments is lowest. This variation is due almost wholly to erosion, though the greater depth in the north may be due in part to the more rapid breaking down of the parent rock under the influence of heavier rainfall. Along the northern edge of the area the soil becomes of a lighter color and grades into the Adjuntas clay.

The Portugues stony loam occupies a single large area between the soils of the south coast limestone hills and the Adjuntas clay of the higher altitudes. The surface of the greater part of the area is rough, hilly, or semimountainous, and characterized by many steep slopes. The hills become more rounded in the southern parts of the area.

This soil is residual, being derived from the weathering of volcanic and igneous rocks. Judging from the depth of the soil, notwithstanding the known excessive removal of soil by washing, the rate of weathering must be comparatively rapid. The soil does not rest upon fresh rock, as in the limestone regions, but passes by degrees through a broken mass of partly disintegrated rock to the solid rock bed below.

In the southern part this soil is devoted largely to stock raising, while in the northern part bananas and plantains are raised in considerable quantities, and some coffee estates, not in the best condition nor yielding very well, are found in the more favorable situations. Nowhere else on this soil is coffee culture so successfully carried on. In some of the deeper soils of the southern border of the type sugar mills have been built and cane planted; but it has been found that the rainfall is insufficient for the profitable prosecution of this industry and stock raising has been substituted by the owners of these plantations.

The following table gives the mechanical analyses of this soil:

Mechanical analyses of Portugues stony loam.

[Fine earth.]

No.	Locality.	Description.	Organic matter	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
6584	4½ miles N. 1½ miles W. of Ponce.	Stony loam, 0 to 14 inches	1.11	20.46	19.36	7.20	10.50	8.78	18.92	14.68
6585	6¼ miles N. 2½ miles W. of Ponce.	Stony loam.....	3.31	10.40	10.70	6.10	11.66	9.50	29.40	22.14

PENUELAS ADOBE.

The Penuelas adobe is a brown loam having the characteristics of an adobe soil, an average depth of 13 inches, and resting directly upon a mass of disintegrated volcanic tufa. The soil is heavy and plastic when wet and is difficult to till, and when dry it bakes and cracks. This type is found only in one area, which, however, is of considerable extent, covering the hills and slopes around the town of Penuelas.

Because of the prevalence of drought in this part of the island this type is used for little except pasture. During the wet season a good covering of grass is produced. Bananas and plantains are found, but only in exceptionally favored positions, where there is sufficient moisture, do they amount to anything.

Mechanical analyses of Penuelas adobe.

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Course sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
6562	1¾ miles NE. of Penuelas.	Light-brown loam, 0 to 15 inches.	1.13	6.20	8.54	5.30	10.98	9.28	23.32	36.28
6561	1 mile N. of Penuelas.	Brown loam, 0 to 13 inches.	1.29	1.56	2.88	2.22	6.70	8.54	31.56	45.90
6563	Subsoil of 6562.....	Gravelly loam, 15 to 24 inches.	.92	30.28	20.66	7.94	13.30	9.40	8.64	9.42

PASTILLO LOAM.

Pastillo loam is a loam soil 4 to 36 inches in depth, but over much of the area nearer the minimum depth. The color shows a wide variation, ranging from almost chalky white to a reddish brown and black. The soil rests directly on limestone rock, of which it contains many fragments.

This type occurs in one large and three smaller areas on the south side of the island, the greatest extent being west of Ponce. The surface is gently rolling. It covers limestone hills of rounded contour and easy slopes.

The soil is of little agricultural value. In a few spots where the soil is deepest there are a few areas cleared and planted in Guinea grass, which is used for pasture or cut for hay. The remainder of the area is covered with a growth of brush which in some places is very dense

and from 10 to 15 feet in height, furnishing a small amount of firewood and perhaps some browsing for cattle. Were the hills free from this growth they would undoubtedly produce much more grass than at present; still, it is very doubtful if the return would pay for the cost of clearing, for over the greater portion of the area the soil is too shallow to support more than a short growth of grass and that only during the wet season.

The following table gives the mechanical analyses of this soil:

Mechanical analyses of Pastillo loam.

[Fine earth.]

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
6565	3¼ miles SW. of Ponce.	Loam, 0 to 4 inches.	13.36	7.54	8.52	3.82	8.14	7.26	40.40	23.60
6564	1 mile N. of Ponce..	Light-colored loam, 0 to 36 inches.	3.22	.86	1.60	1.64	6.60	10.88	51.14	26.88

PONCE LOAM.

The Ponce loam is a dark-brown alluvial loam, at least 3 feet deep, underlain by material of the same or perhaps slightly heavier character. The soil is somewhat heavier than the Ponce sandy loam, is harder to cultivate, and is apt to clod and bake unless stirred when in just the proper condition. It is a strong, durable soil.

Two relatively small areas are found within the limits of the survey, the smaller situated southwest of and near Ponce and the larger southeast of that city. The surface of this type is nearly level, the slope being slight toward the south. Traversing this plain are shallow depressions, marking former courses of the river. These low spots were at one time covered with a heavy growth of swamp vegetation, and as a result the soil is rich in humus.

The soil being very heavy, the drainage is poor, except where the surface is more sloping. Artificial drainage of the depressions was necessary before they could be cultivated.

A small area near Ponce is planted in Guinea grass, large crops of which are cut several times each year. The remainder of this type is cultivated to sugar cane with the aid of irrigation. The yield per acre ranges from 35 to 40 tons per acre, and is equaled by only one other

soil in the area—the Arecibo silt loam. As regards sugar content, the product of the Ponce loam is the first in the area. On some of this land sugar cane has been cut annually for a great number of years, and the rate of yield and the fertility of the soil has decreased as a result, though the yield probably averages twice that of the Southern United States.

The following table gives a mechanical analysis of this soil:

Mechanical analysis of Ponce loam.

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Course sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
6566	½ mile SW. of Ponce.	Dark-brown loam, 0 to 36 inches.	1.34	0.24	0.84	0.60	4.68	15.30	57.46	20.06

PONCE SANDY LOAM.

The soil of the Ponce sandy loam consists of a dark-brown sandy loam of fairly uniform texture, varying in depth from 2 feet to perhaps 10 or 12 feet. This is underlain by material of much the same character, varying slightly, being heavier than the surface soil in some places and lighter in others. A light phase also occurs along the river courses, where the surface soil is quite sandy and contains a few pebbles. In one or two places gravel was found scattered about on the surface or deposited in small channels cut in the soil. However, these variations were of little importance. This type occupies the level playa plain on the south side of the island, representing the flood plains of Tallaboa, Mayaguez, Portugues, and Bucana rivers and their tributaries. The plain has a moderate slope toward the ocean, but its surface is somewhat uneven and broken because of the shifting of the rivers, which have wandered to and fro over it.

It follows that this soil is of alluvial origin, the material of which it is formed being the finer particles of sediment borne by the rivers during floods from the hills and mountains farther back from the coast. The uniformity of texture and the fineness of the particles are due to the distance from the source of erosion and to the slower currents of the streams in this part of their courses.

There are two small bodies of a stony phase of this soil found in the area surveyed. These occur as narrow strips extending short distances along the Portugues and Tallaboa rivers, to which streams the

formation is due. The material is the coarse alluvium, consisting of loam, sand, and gravel brought down by the rivers from the mountains during the flood season and deposited as the streams adjust themselves to the more gentle slopes of the valleys.

Sugar cane is the principal product grown on the Ponce sandy loam, irrigation of course being necessary. The yield is not so large as on the Ponce loam or the Arecibo silt loam, averaging from 30 to 35 tons per acre, or about 5 tons less than the yield of the two leading cane soils of the area. The sugar content is higher in the Ponce sandy loam, while the yield is almost if not quite equal to that of the Arecibo silt loam. The cane is grown year after year on the same fields, and there is a slight decrease in the yield from year to year.

Guinea grass is the crop next to cane in importance. Large fields in and around Ponce are devoted to its cultivation to supply the forage demand of the city. The grass is cut green, tied in bundles, and delivered fresh to the consumer each day. Like alfalfa, as soon as cut Guinea grass begins to grow again, and where sufficient water is furnished a large yield is cut several times during the year. Shade is supposed to increase the growth, and in the best fields mocha and other trees have been planted for this purpose.

Around several of the cane plantations fields of bananas, ranging from small patches up to 10 acres in extent, are planted, principally to supply the laborers with the fruit. The trees in these fields are very large and well loaded with fruit and this soil no doubt gives by far the largest returns per acre of any land in the area. A few cocoanuts are grown along the plantation boundaries, roads, and ditches, and in the latter places particularly the nuts are large and the yield very high—probably even higher than on the coral sands. A yield of 700 bunches of bananas per acre in one year has been grown on this soil. Sugar cane is now the great staple crop upon this soil type, and while it is very productive when cultivated in bananas and cocoanuts it is doubtful if it should be used in the commercial production of these crops as long as cheaper lands nearly as good for the purpose are obtainable. No attempt has been made to grow the citrus fruits on this type, but it is believed that with irrigation oranges and lemons would do exceptionally well.

A few attempts have been made to farm the stony phase of this soil to cane, but it seems these have not been profitable and all of the soil is at present used for pasture. A few cocoanut trees are also grown, but on account of the lack of moisture the yield is very light.

The table on the following page shows the texture of the soil and subsoil of this soil type.

Mechanical analyses of Ponce sandy loam.

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
6568	2 miles W. ¼ mile N. of Ponce.	Light-brown sandy loam, 0 to 14 inches.	2.30	0.52	1.30	2.64	24.40	23.76	39.26	8.08
6570	1½ miles S. of Ponce	Light-brown sandy loam, 0 to 15 inches.	1.08	Tr.	.40	2.12	31.02	25.80	31.16	9.16
6579	1 mile N. ⅛ mile E. of Ponce.	Dark sandy loam, 0 to 36 inches.	1.08	3.30	8.40	8.10	24.00	21.24	22.84	11.92
6572	2¼ miles SE. of Ponce.	Light-brown sandy loam, 0 to 36 inches.	1.46	2.30	1.86	1.70	10.54	19.98	50.82	12.50
6578	1 mile W. of Penuelas.	Brown stony loam, 0 to 26 inches.	.84	1.90	8.08	11.20	28.62	15.40	20.72	14.08
6567	7½ miles W. of Ponce.	Alluvial soil, 0 to 36 inches.	.08	1.56	3.50	2.66	11.90	20.66	42.80	16.42
6571	Subsoil of 6570.....	Fine sandy loam, 15 to 36 inches.	1.19	.20	.30	.40	6.34	17.52	58.22	16.86
6569	Subsoil of 6568.....	Dark-brown loam, 14 to 36 inches.	.71	Tr.	.76	.80	6.90	13.50	56.02	21.76

TANAMA STONY LOAM.

The area mapped as the Tanama stony loam represents a group of soil conditions rather than one particular soil type. The prevailing type, however, consists of a red clay, generally shallow—only 2 or 3 inches deep—but frequently having a depth of several feet. The soil contains from 30 to 60 per cent of angular limestone fragments. Where the soil is more than a few inches deep the clay content increases considerably in the lower depths. Beneath the shallow covering of soil occur masses of broken limestone, or more often limestone in place. Usually the red clay is found to a greater extent on the upper slopes of the rough and broken land, but often one can travel for miles and find the red clay not only on the slopes but also in the small local bottoms or depressions. The soil is soft and unctuous, containing no noticeable particles of sand or any other than clay material.

Closely related to the red-clay areas are small areas of black adobe-like loam, which are interspersed throughout the area occupied by this formation. This loam is identical in almost every respect with the soil which has been described as Arecibo loam. In the small areas the depth of this black, tenacious loam rarely exceeds 6 inches, beneath which lies a shallow brown and occasionally red loam. The areas of this black loam are for the most part small, and although they sometimes occur on the higher slopes and on the crests of the hills, more fre-

quently they are found on the lower slopes and in the depressions between the hills, wherever there is an accumulation of organic matter. Frequently in the small depressions swampy conditions prevail and cultivation is impossible. Where the drainage was still further obstructed the depressions contain small ponds.

In many places rock walls, with perfectly bare surfaces, from a few feet to more than 150 feet in height were observed. Occasionally a bush or shrub may be seen clinging to some crevice, but in most cases the rocks are devoid of vegetation, except, perhaps, the overhanging roots of trees or shrubs growing on the ledge above and the long vines which extend to the bottom of the cliff. Frequently on the crests of the hills, where there is only a slight soil covering, the limestone is so porous and open and the conditions of heat so favorable that many plants and trees and even a thick covering of grasses find a footing on what might be termed the bare rock surfaces. Often small, angular hills, rarely exceeding more than a few acres in extent and from 100 to 200 feet in height, from which the thickly matted jungle of trees and underbrush had been removed, were seen supporting a thick growth of long grass. A careful examination of some of these hills failed to reveal any soil covering whatever. (See Pl. III.)

The principal area occupied by the Tanama stony loam is situated on each side of the Arecibo River, commencing 4 miles south of Arecibo and extending to the junction of the Limon and Caguantas rivers with the Arecibo. It covers the greater portion of the area described in the physiography under the name of eroded limestone plateau or foothill region which lies to the north of the central mountainous region. At the southern extremity of this soil formation the hills range in elevation from 100 to 200 feet, from which they gradually rise to the southward until, along the line of contact with the mountains, they attain an elevation of nearly 1,000 feet above sea level. This region was undoubtedly at one time a continuous table-land sloping gradually seaward. It is now so pitted and broken that its once level character can only be realized by viewing it from the top of one of the surrounding hills. Although the hills attain a height of 1,000 feet along the southern edge, the difference in elevation of the summit of the hills and of the bottom of the intervening pits seldom exceeds 500 feet. Along the northern and southern boundaries of this soil area the intervening valleys are frequently larger than in the central portion, where the hills are more closely packed together. Travel on the narrow and winding trails that cross the greater portion of this area is exceedingly slow and laborious.

This region is drained almost entirely by underground streams. Only the Arecibo and Tanama rivers cross it, flowing through deeply cut canyons. Nearly all of the depressions have holes in them which serve as outlets for the heavy rainfall or for the water from the springs

which are frequently found on their southern side. When the underground streams become clogged, the swampy condition previously mentioned arises and in some cases the water accumulates to a depth of several feet.

This soil type has been formed from the hard and soft layers of the chalky white limestone of Miocene age. The soil is residual and represents only the insoluble parts of the limestone after it has been thoroughly decomposed and leached by the abundant rainfall. Disintegration plays but little part in the formation of this soil, for the broken fragments of scattered rock through the soil show few traces of disintegration, but are comparatively fresh and solid. That the erosion of this area has been brought about by solution is readily seen when one considers that nearly all of the rainfall flows away to the sea by underground streams and observes that the region is fairly honeycombed in almost every direction by numberless caverns.

Over the greater part of the area bananas and plantains form the leading crops. Yantia, sweet potatoes, gondules, and melanga and other minor produce crops are grown to a considerable extent. Coffee is cultivated, but the greater part of this soil is too stony to allow the coffee roots to become well developed. The best coffee is grown in the southern part of the area, but it is inferior in quality to coffee grown on the Adjuntas clay, particularly in the higher altitudes, bringing about $3 less per 100 pounds. It is frequently the case that the small areas on the angular hills, where almost nothing can be seen but a mass of blocks of white limestone, are selected for tobacco, and it is said that these are more favorable situations for this crop than the lower slopes, where deeper soils are usually found. Possibly in such localities the conditions of light and warmth are more favorable to the rapid maturing of this plant, for the rocks absorb the heat from the sunshine during the day and remain quite warm during the night. It is only with abundant dew and frequent showers that a crop of any character can be raised in such unfavorable situations. The quality of the leaf is said to be very good. A sweet, well-flavored orange is grown on this soil, and the trees noticed seemed to be in fairly good condition.

Undoubtedly the red clays and black loams are fertile soils, but the rough, broken character of the country is decidedly against any great agricultural development in these regions. The trails are so difficult that transportation of large quantities of any product will always be a serious problem. At present all the products of this region are either carried on the heads or shoulders of the peons or on the backs of the small, hardy horses and mules that are raised on the islands. With the exception of the military road between Arecibo and Utuado, nothing but rough, winding trails (and only a limited number of these) traverse the area.

The table on the following page shows the texture of typical samples of the red clay and black loam soils of this area.

THE TANAMA STONY LOAM, PORTO RICO, SHOWING THE VERY ROUGH AND RUGGED TOPOGRAPHY, ALMOST INACCESSIBLE AND IMPASSABLE, MUCH OF IT INCAPABLE OF CULTIVATION.

Mechanical analyses of Tanama stony loam.

[Fine earth.]

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
6488	5 miles NE. of Utuado.	Rich, black, tenacious loam, 0 to 6 inches.	7.76	0.77	1.68	1.61	9.04	7.43	45.08	34.41
6486	5 miles S. of Arecibo.	Clay loam, 0 to 10 inches.	1.77	.23	4.71	5.47	17.38	10.07	13.33	48.29
6489	5 miles NE. of Utuado.	Stiff red clay, 0 to 8 inches.	3.82	.00	2.01	2.22	6.72	3.26	35.29	49.78
6487	Subsoil of 6486	Stiff red clay, 10 to 30 inches.	1.82	Tr.	2.84	14.19	41.82	7.58	5.18	28.79
6490	Subsoil of 6489	Stiff red clay, 8 to 24 inches.	1.92	.43	2.78	3.19	11.05	3.94	25.55	51.14

WATER SUPPLY FOR IRRIGATION.

Irrigation on the north side of the island is only necessary in the cane fields in the dry seasons. The application of water during this period undoubtedly increases the growth of young plants and keeps the mature cane in a better condition for grinding, and there is an abundant water supply in the Arecibo River which can be made available for irrigation at very little cost.

On the south side of the island much of the arid land lies high up in the mountains or on the tops of the limestone foothills, and is unirrigable on account of its position. Within the area surveyed all of the available river water during the dry season is now used for irrigation. This supply, however, is inadequate, much of the young and some of the old cane showing the effect of drought. The supply should be supplemented by pumping from driven wells. This method has not as yet been attempted, but there are indications that driven wells would reach a good supply of water at moderate depths. The character of the water now used in irrigation is excellent.

The best quality of cane and the largest yields of this product, of bananas, plantains, and Guinea grass produced in the area, are obtained from the irrigated lands about Ponce, and with enlarged and perfected irrigation systems, so that the supply of water need never be short, not only will the acreage of cultivated land be extended, but the average yields will be materially increased.

UNDERGROUND WATER AND DRAINAGE.

During the wet months the level sugar lands of the north side are to a certain extent affected by the rising of the water table, which at

that time comes to within a very slight distance of the surface of the ground. This, if not injurious to the growth of the cane, at least lowers the sugar content. The water table can be controlled by drainage, and is in a measure so controlled. This is generally done by means of open ditches which divide the field into many small tracts, thus interfering more or less with cultivation. Tile drains for carrying the surplus water off underground would be a great improvement over the present method.

There are several areas of swamp and other lands that are at present covered with water, or are too wet to permit of cultivation, which can be turned into valuable cane lands by drainage. In some places, on account of the slight elevation, the fall would not be adequate to keep the drains dry, and pumping plants would therefore have to be installed to move the water. It is doubtful if the profits to be made at present in the culture of sugar cane—the crop best adapted to such land—would pay for the reclamation of the less advantageously situated of these wet lands.

ALKALI IN SOILS.

Very little of the soil of the area was found to be alkaline, and all affected areas, with the exception of a strip along the Tiburones Canal, occur on the south side of the island. The areas there are low lying, and can not be reclaimed by underdrainage except by the use of dikes and pumps. The sea is thought to be the chief source of the salt in this area.

AGRICULTURAL METHODS.

In general, the agricultural methods of the island are primitive as compared with the methods in use in the United States. The implements and machinery, except on some of the large sugar and coffee estates, are antiquated and do the work for which they are intended but imperfectly. In many of the districts wooden plows are still used to stir the ground, while the bulk of the other farm operations falls upon the machete—a heavy sword or cutlass.

The care of the soil as it is understood in this country—the maintenance of its fertility by the addition of manures or fertilizers and the husbanding of its resources by the rotation of crops—is practically unknown in the island agriculture. The nearest approximation to this is allowing the land to "rest," i. e., throwing it out of cultivation for a year or two. These lands are generally used as pasture for the work oxen.

It is needless to say that under such conditions the fertility of the soils have greatly deteriorated. This is shown by comparing the present yield of the sugar-cane soil, which has perhaps been most

intensively cultivated, with the yield fifty or one hundred years ago. The decline has been marked, and in all the island there is said to be but one exception to the general rule—the cane lands of the tributary island of Vieques. Nevertheless it should be borne in mind that the average product per acre in Porto Rico is about twice that of Louisiana, and that the cane grows from rattoons for from four to seven years after planting, while in Louisiana the fields must be planted anew each year.

To obtain some light upon the chemical nature of these Porto Rican soils a number of samples were analyzed in the laboratory according to the method of the Association of Official Agricultural Chemists, and from the data thus obtained the following observations were made:

The Adjuntas clay runs high in alumina (Al_2O_3) and iron (Fe_2O_3), containing about 20 per cent of the former and from 10 to 20 per cent of the latter substance, the iron running much higher in the subsoil than in the surface soil. The soil was rich in lime (CaO), containing about 0.5 per cent, and is apparently well supplied with nitrogen (N), containing about 0.15 per cent. It runs low in phosphoric acid (P_2O_5), containing only about 0.03 per cent, and shows but traces of potash (K_2O). In these latter two important plant foods this soil seems to be decidedly deficient.

The Alonso clay was found to contain about 14 per cent of alumina and about the same amount of iron oxide. It contains about 0.25 per cent of lime and more than three times this quantity of magnesia. It is well supplied with potash, about 0.6 per cent, and with nitrogen, about 0.12 per cent, and but fairly well with phosphoric acid, about 0.08 per cent.

The Pastillo loam contained about 2 per cent each of alumina and ferric oxide. It ran very high in lime, containing over 50 per cent of this substance. It was fairly well supplied with nitrogen, about 0.14 per cent, but was low in potash, 0.15 per cent, and contained but little more than a trace of phosphoric acid.

The Ponce sandy loam contains from 8 to 10 per cent of alumina and from 6 to 8 per cent of ferric oxide. It is well supplied with lime, from 2.5 to 5.5 per cent, and with potash, from 3 to 4.5 per cent. It contains about 0.09 per cent of phosphoric acid, although one sample examined ran as low as 0.03 per cent in this constituent. It seems fairly well supplied with nitrogen, containing about 0.12 per cent.

The Portugues adobe contains about 9 per cent of alumina, 5 per cent of oxide of iron, and is rich in lime, from 12 to 16 per cent. Of potash about 0.4 per cent was found, of phosphoric acid about 0.2 per cent, and of nitrogen about 0.25 per cent. A sample of subsoil in this formation showed over 1 per cent of sulphuric acid (SO_3), probably combined for the most part as gypsum, but the surface soil to a depth of 17 inches taken at the same spot showed but 0.03 per cent.

All these soils, excepting possibly the Alonso clay, are rich in lime. While well supplied with magnesia, this soil constituent never approximates in amount the lime, except in the case of the Alonso clay as cited above, and this fact is a notable characteristic of these Porto Rican soils, no matter what their origin may have been. Excepting the Adjuntas clay, all the soils examined seemed to be well supplied with potash and fairly well with phosphoric acid. All may be considered as fairly well supplied with nitrogen, and under good cultural methods crops should not suffer seriously for the lack of this important and expensive plant food.

Coffee is the leading product of the island at large and of the district surveyed, though no statistics can be segregated for the fractional part of the district of Arecibo and Ponce which the survey covers. The principal coffee districts are around Adjuntas and Utuado, and the soils best adapted to the cultivation of this crop are the Adjuntas clay, the Alonso clay (high area southwest of Adjuntas), and the Utuado loam. The northern part of the large area of Portugues stony loam and the southern part of the even more extensive Tanama stony loam also produce some coffee.

The method of cultivating this crop, which differs little in the different areas, is as follows:

If the land is virgin, it is first cleared of trees and underbrush with the machete; then holes are dug, also with the machete, at the proper intervals, and the seedling trees are set out; or if the plantation is to be started from the seed, which is rarely the case, these are pushed into the soil and covered. Before or at the time of setting out the trees plantain or banana slips are also put in here and there to furnish shade during the first five years' growth. Guava trees are also set to furnish shade during the following years of growth.

The coffee trees begin to bear a little the fourth year from planting, but do not come into full bearing until the eighth year. The life of the tree, if given good care, is from fifteen to twenty years. As at present grown the coffee plants are greatly overcrowded as well as overshaded. The yield varies, the best managed estates gettir from 200 to 400 pounds per acre.

The harvesting is a laborious process, the berries being picked by hand as they ripen. The ripening of the berries is not uniform, and the plantations have to be gone over by the pickers several times to complete the gathering of the crop. Men, women, and children do this work, for which, on some plantations, they are paid by the weight of the green berries picked—about 40 cents per 100 pounds. A man can gather, where the trees are well filled with fruit, perhaps 100 pounds a day, but where the crop is poor or after the plantation has been gone over the amount is necessarily much smaller. Where wages are

paid 35 cents a day is about the average, and this not all in money, but part in supplies advanced by the stores.

The coffee plantations are not cultivated. The situations are often very steep, and the roots of shrubs and vines are depended upon to a great extent to hold the soil in place. The undergrowth is kept down with the machete, and this generally constitutes the entire care.

After the gathering of the berry the preparation of the coffee for the market partakes rather more of the nature of manufacture than agriculture. The methods employed on the island vary all the way from the use of the simplest devices by the peons in the preparation of the few pounds they may gather from wild trees or filch from neighboring estates, through rude machinery worked by water or horse power, to the large mills equipped with modern types of machinery and usually operated with steam engines. Not to go into the details of the preparation of the coffee berry, the method consists of the removal of the pulp, the separation of the twin coffee grains, the drying and removal of the hull which envelops these, and the grading, polishing, and coloring of the coffee bean.

The coffee of Porto Rico goes almost entirely to Cuba, France, and Spain, and the average price paid by the exporters in the coast towns is about 10 cents per pound. Up to the time of the American occupation of the island little if any of this coffee came to the United States. It is said to be of a quality superior to the South and Central American coffee, which practically monopolizes the United States market. The South American coffee brings a much lower price to the grower than the Porto Rican, but with closer trade relations established with this country doubtless Porto Rican coffee will soon find a place as a high-grade article in our market.

On a few coffee estates small areas have been fertilized with barnyard manure, coffee hulls, or guano. On gentle slopes the fertilizers were spread broadcast over the surface, while on the steep inclines it was dumped in piles and allowed to leach downhill, or put in holes about 1 foot square and 1 foot deep between the plants. The latter method proved more satisfactory because of the less loss by washing. With heavy applications of the fertilizers the coffee plants are said to more than double their yields.

In many of the caves which practically honeycomb the limestone portion of the island bat guano covers the floor in places to a depth of several feet. There are thousands of tons of this guano thus safely stored away in the mountains. In some localities the guano is hauled out and delivered for $3 per ton. At this price it is cheap plant food and its use can be recommended.

The preparation of the soil for sugar cane is more elaborate than for coffee. The land is usually plowed three times (the heavier soils four times) before the canes are set out. Ditches and drains are dug, and

the cane is set on the sides of ridges, with a drainage furrow between the ridges, the land being laid out in such a manner as to allow the alternation of the ridges and furrows from year to year. The crop is weeded usually four times, and this is followed by the operation called "thieving," i. e., pulling the lower blades of the cane and laying them between the rows, where they form a mulch and keep the weeds and grass from growing. This represents the course of cultivation in a newly planted field. The labor is somewhat less in subsequent years. The cane reproduces itself from rattoons, and can be profitably grown without replanting for from four to seven years, though it is thought annual planting, using the modern methods employed in Louisiana and Hawaii, would return even greater profits.

In harvesting the cane is cut and hauled to the mill in ox carts, or on some of the best equipped plantations steel tramways with portable extensions run between the fields and the mill. The transportation of the cane to the mill is a laborious and expensive process, and where the haul is long it often turns the scale from profit to loss.

Fertilization of the sugar-cane lands is not commonly practiced, but experiments have been tried on certain estates with success. It was found that 1 cubic foot of stable manure to the hill gave better results than 1 pound of guano, the effect being more noticeable in the vigor of the rattoons and the increased productiveness in the second year than in the yield from the planted cane. Liming the soil has also been tried and is said to give good results.

The important sugar-cane soils are, in the order of preference, the Ponce loam (irrigated), Arecibo silt loam (unirrigated), Ponce sandy loam (irrigated), Portugues adobe (irrigated), and Vivi sandy loam (unirrigated). Between the first two types there is not much choice, the higher sugar content of the product grown on the one about compensating for the higher yields on the other.

The cultivation of tobacco follows more or less the methods employed in Cuba. The plants are transplanted from seed beds to the carefully prepared fields and given clean culture. The plants are budded, and a close watch is kept for the eggs and larva of the tobacco worm and other insect pests. Several crops are gathered from the same field in a single season.

While the methods of cultivation and curing are in many ways similar to those employed in Cuba, the Porto Rican grower is not generally as skillful as the Cuban. The industry has not reached as high a state of development as it has on the larger island.

The fields within the area surveyed are for the most part small patches, and this in itself is against the proper curing, sorting, and grading. In fact, the grower seldom attempts any grading at all, but sells his product in bulk, the grading being done by the exporter or the manufacturer.

The tobacco is cured without the aid of artificial heat, the time of curing being about forty-five days. In some parts of the island the tobacco barns are loosely constructed sheds, generally built lengthwise up and down the hills, so that a draft will blow through them as through a chimney; but in the area surveyed the barns, which were heavily thatched, were built horizontally and without regard to special ventilation.

The best grade of tobacco, which is grown in the mountain regions, compares favorably in natural characteristics with some of the better classes of Cuban tobacco. The Vivi sandy loam produces the finest leaf in the area, the Arecibo silt loam (sandy areas along the upper course of the river) having second place, the Adjuntas clay third, and the Tanama stony loam fourth. Tobacco on the Portugues stony loam is grown under irrigation.

Up to this time coffee, sugar, and tobacco have been the chief exports from the island. Besides these crops there are a large number of fruits produced on the island, some of them cultivated, but many of them growing wild, and the minor subsistence crops, important among which are tanier, sweet potatoes, cassava, upland rice, beans, and corn. As yet in the areas surveyed little attempt has been made to grow any of these products on a commercial scale, but there seem to be good prospects, with the close trade relations which now exist between the island and the United States, for the development of favorable industries in the production of citrus fruits, cocoanuts, pineapples, and bananas, as well as some of the other fruits not as well known in the markets of this country; for instance, the guava in the shape of jelly.

Citrus-fruit culture as it is carried on in California and Florida is practically unknown in Porto Rico. The orange, which is the most important and most extensively grown of these fruits, is planted among the coffee trees, in the shade along the trails, and around the houses, but after planting little else is done to promote the growth and productiveness of the trees, except that on some estates the grass is occasionally cut from beneath them. With the little care just mentioned the trees grow vigorously and bear an abundance of fair fruit, sweet and of good flavor, and with small amount of pulp, medium thick skin, and good color.

Considering that nothing has been done to improve the native stock by budding or grafting, all the trees being seedlings, the fruit is very fine. Undoubtedly it could be improved by grafting from scions from selected trees on the island or by introducing some of the choice varieties from other orange-growing districts.

A few dozen lime trees were observed scattered through the area. They were of good color and bore considerable fruit, and there seems

to be no reason why this fruit should not be grown successfully on a commercial scale.

Only a very few lemon trees bearing a coarse, inferior fruit, used only to a limited extent, were noticed. This same variety is grown in California gardens as a curiosity. The production of this fruit seems to be neglected. A fair idea of the lemon output may be drawn from the fact that the Italian product is the only kind to be found on the market. The pomelo, or grape fruit, reaches perfection on the island.

The cultivation of citrus fruits is recommended for the Adjuntas clay, the Alonso clay, particularly the high-lying areas to the southwest of the town of Adjuntas, and the Tanama stony loam, in such locations as are near enough to the military road to permit of the transportation of these crops to market. On all of these soils these crops could be produced without the aid of irrigation. On the south coast of the island, where the climatic conditions and soils are in some ways similar to those of southern California, the raising of citrus fruits under irrigation could be profitably undertaken. The Ponce sandy loam is one type of soil recommended for the growing of oranges. Near Mayaguez, in the extreme western part of the island, there are a few successful commercial citrus-fruit orchards, and there is no reason why other successful orchards should not be established on some of the soils of the area surveyed, and the direct water transportation between the island and New York, together with the low freight rates, should encourage capitalists to embark in the development of this industry.

To no other two products do the natives owe so much as to the banana and plantain. From playa plain to mountain top, wherever any cultivation has been carried on, the beautiful plants, of various heights, with broad, herbaceous leaves, 8 or 10 feet long, are seen. Bananas and plantains are grown from the suckers which appear at the base of large trees. These are separated from the parent tree with a spade or knife and transplanted. In one year from the time of planting the first fruit may be gathered. Bananas are always cut green, fifteen or twenty days before maturing, and hung in the dark to ripen.

There are more than a dozen varieties of bananas grown in the area surveyed. The "date" and "apple" varieties are by the natives considered the choicest. The former is about three or four inches long, with very thin skin, while the latter is a little longer. The plantain so closely resembles the banana that it takes an expert to tell them apart. There are many varieties on the island, the choicest of which are known as "hortones" and "congos." The fruit is gathered green and always prepared for eating by cooking.

Both bananas and plantains are used to a large extent to shade the coffee trees, especially the young plants. Better transportation facilities and the demand that is almost sure to arise in this country will soon develop the production of these crops along commercial lines.

BANANA GROVE ON ARECIBO SANDY LOAM, NEAR SANTA ANA, PORTO RICO.

In the stony and mountainous areas the banana, plantain, and coffee trees are put out often in small patches, receiving little or no attention and in areas impossible of cultivation.

At present the soils on which bananas and plantains are more successfully grown, given in the order of precedence, are as follows: Ponce sandy loam, Arecibo silt loam, Ponce loam, Portugues adobe, Adjuntas clay, Alonso clay, and Tanama stony loam. When the question of commercial production is considered, the order may be changed somewhat, as cost of production and of transportation to market will enter more largely as a factor in the profitable growing of these crops. The best banana lands may yield as high as 700 bunches on a single acre in one year. (See Pl. IV.)

Probably the most valuable of the indigenous trees of the island is the cocoanut palm. It is cultivated to considerable extent in the area surveyed, but most successfully on the sands along the seacoast. The soils on which it does best are the Ponce sandy loam, the Coral sand, the Arecibo sandy loam, the Arecibo sand, and the Arecibo silt loam. Near the coast, where the water table comes near to the surface, the trees were particularly thrifty, on soil that is almost worthless for any other purpose.

The cocoanut palm grows to a height of 50 feet or more and is crowned with fronds from 12 to 15 feet in length. The fruit is borne in clusters, from 2 to 15 nuts in a cluster, and one tree sometimes bears as many as 150 nuts. As many as 10,000 nuts may be produced on one acre in one year. The tree begins fruiting when 5 years old and may continue to fruit for one hundred years.

Cocoanut trees require no cultivation when once established, but the gathering of the nuts is difficult and expensive, as is also the freeing of the nuts from their fibrous husks. No extensive plantations were seen in the area, but a few are sold for export, bringing from $12.50 to $20 per thousand. In the eastern part of the island some attention is given to the commercial production of this nut, and in 1890 1,500,000 cocoanuts were exported from the island, principally to the United States.

The Porto Rican pineapples are acknowledged, even in Cuba, to be the finest flavored in the West Indies, and yet but few are exported—only 50,000 in 1898. Within the area surveyed at present pineapples, with one or two exceptions, are grown only in small patches for home use, the poorest reaching the local markets. There is excellent opportunity for the introduction of the commercial growing of this crop. Certain of the cheapest sandy soils are very similar to the pineapple lands of southern Florida, and with the same high fertilization and intensive culture would probably become equally as valuable.

The guava, cassava (from which comes the commercial tapioca), and a number of other native crops also promise to become of economic importance when transportation facilities improve and the needs of the United States markets become understood in the island. The growing of some of the vegetables for early marketing in the United States might be profitably developed.

AGRICULTURAL CONDITIONS.

At the time of the occupation of Porto Rico by the United States, agriculture in the island was greatly depressed. The low price of sugar in recent years had closed many of the mills and thrown out of cultivation wide areas of fertile sugar lands; the war in Cuba had unsettled trade with the mother country, and oppressive taxation, made more onerous in the attempt to make the little island bear a disproportionate part of the extraordinary expenditures necessary for carrying on the war, had discouraged those who were able to start new enterprises or to revive those in decline by the investment of capital. As a result of these untoward circumstances many of the laboring class were already out of employment when the disastrous hurricane of September, 1898, occurred. Although this storm did great damage to the sugar industry, it was the coffee plantations which suffered most heavily, and thousands of laborers in the coffee districts of the area surveyed were added to the army of the unemployed.

At the time of the present survey the damage wrought by the storm was still apparent on every hand, and the condition of general depression was only too evident, though matters were beginning to mend, primarily as the result of new governmental policies.

The removal of all personal taxes, the abolishment of the consumer's taxes on food and articles of necessity, the establishment of free trade between the island and the United States, and the hiring of thousands of laborers in the construction of roads are some of the acts of the new régime that are tending to relieve the situation.

While the farming class is as yet far from being in a prosperous condition, the noticeable improvement in that respect that has taken place in the last three years, together with the admitted opportunities for the development of paying agricultural industries and the certainty that capitalists will be found to develop them, holds out hope for the future.

A greater proportion of the farms in Porto Rico are owned by the occupants than in the United States, or than in most of the States taken individually. If we may take the percentages of the departments of Arecibo and Ponce as representing the area surveyed, between 96 and 97 per cent of the farms are owned and but something over 3 per cent are rented. When the land is rented to the peasant class, one-half the crop is the usual return to the owner, the tenant performing all the labor of clearing the land and caring for the crop. In the island at large 89 per cent of the cultivated area is occupied by whites, and 10 per cent by negroes and persons of mixed blood.

The average size of the farms in the area surveyed is probably not far from 50 acres, or a little more than one-third the average size of farms in the United States, and the average area cultivated is about

one-fourth of the total area, while in the United States about one-half of the farm land is on the average improved.

The labor is performed largely by the peons, as they are called. The wage paid is about 40 cents per day, though in the sugar districts the rate is occasionally 50 cents. The latter rate is being paid where extensive operations in road building are being carried on. Often the employer gives the farm hands the midday meal.

The Porto Rican laborer is faithful and industrious, and, while he is illiterate (83 per cent of the entire population of the island is unable to read), he is intelligent, apt mechanically, willing to learn, and appreciative of fair treatment. With all the difficulties in the way of learning, the proportion of the literates in the island increased from 8 per cent in 1860 to 16 per cent in 1899. With the institution of the free school system the lifting of this class to a higher intellectual plane should progress rapidly.

With the low wage rate and the lack of opportunities for steady employment it is no wonder that great poverty is common among the laboring class. Were it not for the practice of frugality on the one hand and the lavish production of wild and cultivated fruits common in tropical countries on the other, so dense a population as that of Porto Rico under existing conditions would soon find itself on the verge of starvation.

In some of the farm work the women and young children assist. In the picking of coffee this is the case, and in the worming of tobacco, and other lighter work; but the women do not work in the fields as a usual thing as they do in Cuba and in some other of the West Indian islands.

Not to repeat what has been written of the crops in the separate treatment of the soils or in the chapter on cultivation, it is thought well to again refer to the principal products, this time with the broader view of their economic worth as a basis upon which to build a lasting agriculture. The production of sugar in this view is of prime importance. The industry should be resuscitated, and it will be. The quality of the sugar must be improved, the processes of manufacture cheapened, and the competition of other regions met. This can be done by the building of large modern mills in situations where sufficient cane lands can be made tributary to keep the machinery going constantly during the grinding season. In other words, there must be centralization—a reorganization of the industry along the lines in which there has already been made some advance. When so reconstructed the production of sugar will play even a more important part in the wealth and prosperity of the island and of the area surveyed than it does at present.

The Porto Rican tobacco is a fine cigar-filler leaf. It has been a practice of Cuban exporters, especially in years of short crops in that

island, to buy the Porto Rican leaf and pass it off as "Habana." The tobacco industry in Porto Rico has scarcely been developed at all, notwithstanding that the quality of the leaf is good. It should be given the same skillful cultivation and curing that is given the Cuban product. Who can doubt that this product will some day be a mainstay in the agriculture of the island? It will affect mainly the central districts of the area surveyed.

Porto Rican coffee is of fine flavor and brings a better price to the grower than South American coffee. It has an established reputation in European markets. As yet it has not found favor in the markets of this country, but there doubtless will be a demand for it when it shall be introduced to that public which insists on a first-class article. It would seem that this market alone should cause a considerable increase in the area of coffee plantations. Coffee is now the most important industry in the interior areas of the area surveyed, and it is destined to become more important.

The fruit industry has been even less developed than the tobacco industry. The quality of those kinds for which there is already demand in our markets is superior, and amelioration of the present condition of the agricultural classes through the building up of commercial fruit growing is sure to take place.

Without drawing further upon the crop possibilities of the area, the above are enough to warrant a conclusion favorable to the future firm agricultural position of this new Territory.

In a region where so little of intensive agriculture is practiced it would not be expected to find the question of the adaptation of crops to soils worked out very carefully. Yet custom, the result of three hundred years, more or less, of empirical agricultural experiment, has determined broad soil-crop relations, and crop distribution is seen to follow soil formation and topography much as it does in the United States. The time has not yet come for much refinement in this direction, but the work of the agricultural experiment station in the island and of the Bureau of Soils will afford valuable suggestions for those that are ready for them.

Though outside of the area, an interesting instance of the progress of adaptation of soils to crops which has taken place around Cayey may be cited. This is the principal tobacco area in the island, producing a very fine grade of cigar wrapper and filler tobacco. Until within a few years the tobacco was all raised on the lower parts of the slopes, where the soils are deep and rich from the wash from the hills, but in some way it was discovered that the tobacco grown farther up the slopes was of even better quality, and the fields have now been extended to the crests of the hills.

Transportation facilities are limited within the area surveyed. Ponce and Arecibo possess harbors, or, rather, open roadsteads, where

steamships call and receive cargoes of sugar, coffee, rum, and tobacco, but on account of the poor harbor facilities it is necessary for the large vessels to anchor offshore at both of these ports, and the cargoes are carried to the vessels in lighters. Two lines of steamships, with weekly service, connect the island with New York, while one of these lines also touches at South American ports. Other lines connect with the other islands of the Antilles and with Central and South American ports, and small vessels ply around the island.

Arecibo is connected with San Juan by the French Railroad, a narrow-gauge road, which carries freight and passengers. This is a part of the system of coast railroad which was originally designed to encircle the island, but afterwards given up. At the present time it runs from San Juan to Camuy, Aguadilla to Mayaguez, and from Yauco to Ponce.

The military road is completed from Arecibo to Utuado and is being constructed across the island. This will probably be finished by the end of the present year (1902), serving as an easy means of communication between the coast and the coffee districts in the interior mountainous regions. There are several ox-cart roads in the vicinity of the large towns, but travel over these during most of the rainy season is slow and painful.

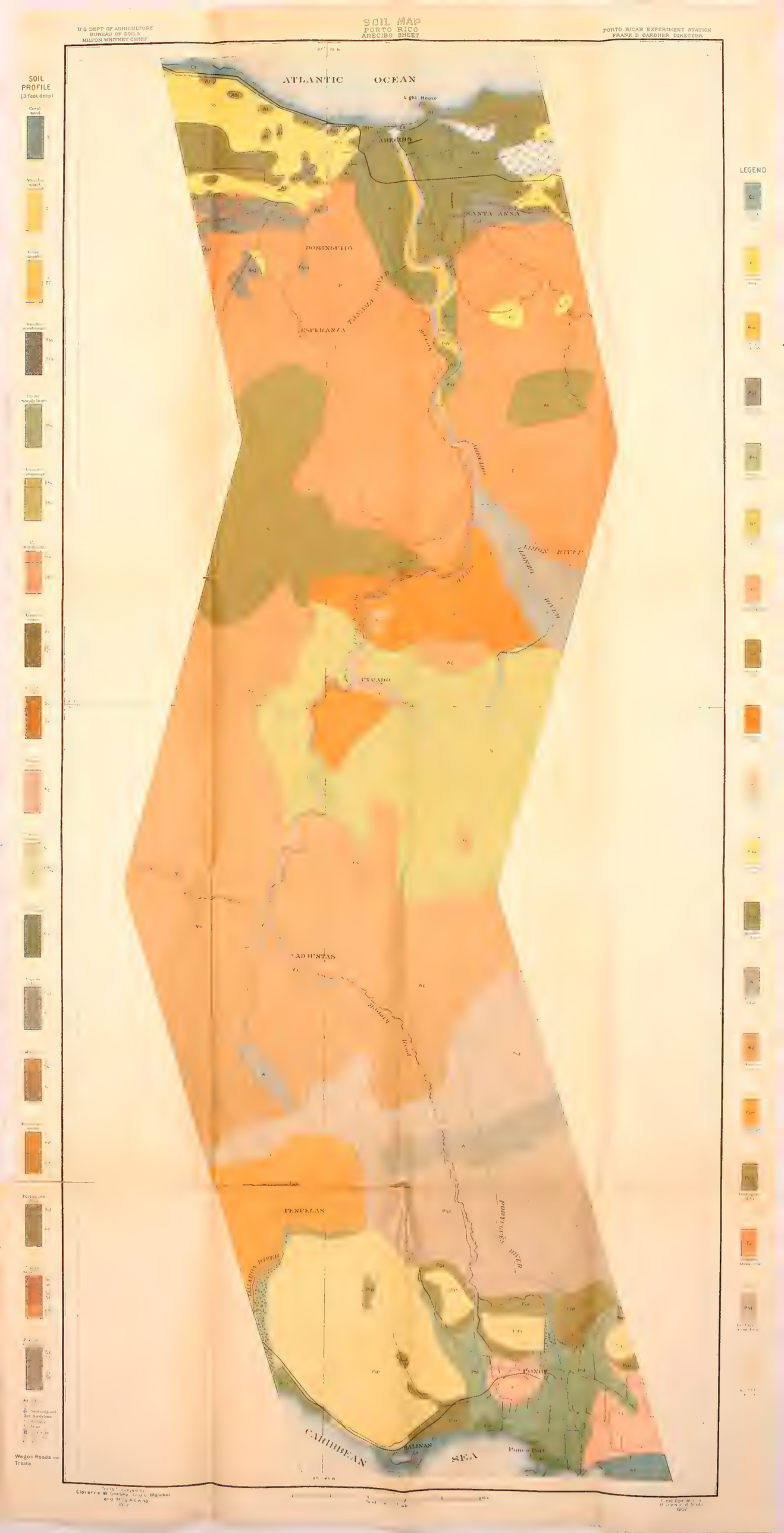
In addition to these roads there are many trails which penetrate the country in almost every direction. These are only passable for pack horses, and frequently during the wet season they are unsafe for travel for either man or beast, on account of the slippery nature of the clay composing them. The question of transportation in the mountainous and limestone hill country is a serious one, and no considerable agricultural development can take place until suitable transportation facilities have been provided.

O

U S DEPT OF AGRICULTURE
BUREAU OF SOILS
MILTON WHITNEY CHIEF

SOIL MAP
PORTO RICO
ARECIBO SHEET

PORTO RICAN EXPERIMENT STATION
FRANK D GARDNER DIRECTOR



Soils Surveyed by
Clarence W Gorsuch U S A, Major
and D U S A Camp
1907

Field Operations of U.S. Bureau of Soils 1907